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ORIGIN OF THE "EPITHERMAL" MINERAL DEPOSITS.[1]

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ABSTRACT.

The problem is outlined. "Epithermal" is defined. The characteristics of "epithermal" deposits are described. The various hypotheses of origin are discussed, particularly the possible relationship to fumarolic-hot spring phenomena. An attempt is made to place the ore mineral phase in a theory of origin. Conclusions are followed by suggested implications.

INTRODUCTION.

THE problem stated by the title has been considered for a century or more, but usually in connection with the theory of origin of all classes of hypogene ore deposits. The "epithermal" type of deposits, however, as it is customarily

[1] Presented at the El Paso meeting of the Society of Economic Geologists and the Geological Society of America, November 10, 1949. Part of the paper is abstracted from: Schmitt, Harrison, "The Fumarolic-Hot Spring and Epithermal Mineral Deposit Environment," Colorado School of Mines Quarterly, vol. 45 (75th Ann. Vol.), no. 1B, Jan. 1950.

classified, is not known to pass to the mesothermal type in depth, and, furthermore, since the described occurrences are nearly all Tertiary in age, there is some justification perhaps for postulating that the "Tertiary type" is in fact unique to the late age of the Earth. Possible transition to the mesothermal type in depth has been suggested for the ore deposits at Casapalca, Bolivia, at Fresnillo, Zacatecas, and for the copper deposits in Michigan. These are three cases out of more than sixty descriptions studied by the writer and the arguments for transitions do not seem convincing.

It seems probable, therefore, that here is a group of ore deposits isolated from the others; more isolated than most of the others appear to be from each other. This is not to deny that this type possesses most of the features of the other hypogene types and is doubtless related to a common broad frame of origin.

The writer has not made an exhaustive study of the problem. He has studied many "epithermal" deposits from the standpoint of commercial appraisal; a few as research problems. He has reviewed many of the data in the literature on sixty "epithermal" deposits of which many are the larger well-known deposits. The conclusions given are largely suggestive and the writer will be repaid if thought is stimulated in this field.

DEFINITION.

Lindgren (11, pp. 203–212)[2] proposed the term "epithermal." It implies an origin at low temperatures and shallow depth. As pointed out by Buddington (2), and others, many of the "epithermal" deposits originated in high temperatures. The term as used in this paper will imply origin at shallow depth regardless of temperature and therefore will be written with quotation marks.

CHARACTERISTICS OF "EPITHERMAL" DEPOSITS.

General.—The general characteristics of these deposits have been described many times, but will be repeated here in review. Although the Michigan copper deposits extend to over 6,000 feet in vertical depth, most described cases of this type seldom exceed 3,000 feet. Features largely unique are: *structural,* increasing fissure complexity upward, in places having the form of a wedge-like or cone-like flare upward; *textural,* crustified, vuggy, drusy, hackly and colloform; *mineralogic,* presence of adularia, alunite, stibnite, barite, fluorite, amethystine quartz, opal, and chalcedony; *presence of the metallic elements,* mercury, tellurium, selenium, arsenic, bismuth, and antimony. Gold and silver bonanza ore bodies with complex sulphosalts of arsenic and antimony are characteristic. Pyrite and base metal sulphides are not abundant. The deposits are commonly associated with areas of recent volcanic activity, volcanic necks, flows and fumarolic and hot spring phenomena.

A review of descriptions of sixty described "epithermal" deposits, indicated features not commonly emphasized: Veins predominate and they generally occupy faults, in many cases major faults. The minerals magnetite, specu-

[2] Numbers in parentheses refer to Bibliography at end of paper.

larite and pyrrhotite, far from being rare, are reported from 13 deposits. Tungsten minerals are common in two provinces of "epithermal" veins: Bolivia and Colorado. They are reported from a total of 10 deposits. Tin is common in this type of deposit in Bolivia where it is found in a minimum of eight deposits. At least five large copper districts seem to be of "epithermal" origin: Michigan Copper, Michigan, Cerro de Pasco, Peru, Los Pilares, Sonora [3] and Ashio, Shimotsuka, Japan.

Age.—The majority of the "epithermal" deposits are middle or late Tertiary in age. Since no Precambrian ones except the Michigan copper deposits have been described and since extensive terrains of shallow volcanic and sedimentary rocks of Precambrian age have been preserved, Schmitt (18) suggested that the "Tertiary" type may be unique to the late age of the Earth. There are a number of objections to this hypothesis. They include: many "epithermal" deposits accompany high volcanic terrain and are eroded rapidly; the mercury of the mercury deposits would be unlikely to survive the heat and pressure of deep burial; and, further, it seems highly probable that shallow deposits of some kind were formed in Precambrian time. The probability may be high, however, that these were unique in character as compared with the Tertiary deposits. Thus, note the Michigan copper deposits.

Structural Features.—The structure of the deposits varies from simple veins to complex stockworks, and intricate branching. The writer has been impressed by the many cases where the structure flares upward in cone-like to wedge-like forms corresponding to the outline of shallow dome intrusives, etc. In both cases it would seem that the surface of the earth, as in blasting terminology, can be conceived to be a free face. This relationship favors cone-like or wedge-like flares upward to accommodate expansion toward the free face.

Telescoping and Zoning.—The crowding and overlapping of different metallic zones, called telescoping by J. E. Spurr (21) is unique as compared with veins of deeper origin, excepting those in carbonate walls. This phenomenon is explained as caused by the abrupt change of conditions vertically in the meteoric water shell. Horizontal zoning is not uncommon in the "epithermal" districts. This, where it is not governed by a change in walls, seems to be the result of temperature variations around "hot centers."

Wall Rock Alteration.—The wall rock alteration of "epithermal" deposits, as disclosed by the literature, presents a confusing picture. The minerals reported are commonly: chlorite, epidote and sericite; less commonly quartz and silicification, calcite and other carbonates, alunite, clay minerals, pyrite, tourmaline (in South America) and rarely albite. The alunite-kaolin-silica alteration appears to be the result of surface oxygen reacting with H_2S and forming sulphuric acid as will be discussed later. It may be called appropriately the "acid-sulphate" type of alteration. Some, possibly important, deep-level oxidation of H_2S would be expected through encounter with ferric minerals,

[3] There is valid objection, perhaps, to calling these two latter deposits "epithermal" even though they appear to be shallow. Obviously veins with "epithermal" aspect can be hot, and deposits of "hot" characteristics even contact pyrometasomatic, can be shallow. Also in basins of depressed isotherms cool deposits probably can be deep. The writer will reserve a discussion to a later paper of the confusion we have now come to in classification.

other relict oxygen and through oxygen entrapped in meteoric water. This could result in hypogene (?) deep-level sulphates.

The quartz-sericite type of alteration with associated adularia indicating accumulation of quartz and potash, as is well known, commonly forms a one to ten foot sheath in the wall on both sides of the vein. This phase appears to be intimately related to the genesis of the early quartz of the veins.

The propylitic phase often described as district wide in "epithermal" areas is usually found in andesitic and basaltic rocks. Lindgren says (11, pp. 457–463) that the propylitized rocks usually show a decrease in silica, lime, magnesia, soda and potassa, whereas additions are usually solely of sulphur and water of hydration. The minerals reported are commonly: chlorite, epidote and sericite; less commonly: quartz and silicification, calcite and other carbonates, alunite, clay minerals, pyrite, tourmaline (in South America) and albite. Characteristically the rock becomes dull greenish and tough. Coats (6, p. 1) remarks, "The degree and type of alteration in rocks that have been described as propylites vary widely, however, as shown by a review of the literature." And finally he says, "It has been shown that the term propylitization has been extended to cover a variety of different types of alteration, and that these types of alteration have been produced in several different ways." The regional character of propylitization is often emphasized as well as the apparent lack of relationship to the veins.

The zeolites appear to be generally deposited within a zone of not more than several hundred feet below the surface. They are common in hot spring deposits, but are rarely reported in "epithermal" deposits: only four cases in 60 descriptions according to the writer's data. They seldom may survive even moderate erosion in most cases. An important exception, of course, is the Michigan copper deposit, the only "epithermal" deposit the writer knows of that has been reported of Precambrian age.

GENESIS.

The Hypotheses of Origin.—The various hypotheses of origin for the "epithermal" type more or less correspond to hypotheses of origin for all types of hypogene ore deposits except that since the type is by definition of shallow origin it is conditioned by association with the meteoric water shell and the atmosphere. Hypotheses of origin that have been seriously considered are as follows:

(1) Lateral secretion.
(2) Fluid "differentiate" from a magma.
(3) Volcanic emanations absorbed by ground water.
(4) Telluric fluids.
(5) Injection in the molten state.
(6) Deposition from the gaseous phase.

None of these can be clearly separated from the other. Nearly all seem to contain elements of truth, except that no one can say where the emphasis should lie. Lateral secretion, one time in vogue, became anathema, but recently again has been seriously discussed (Stewart, 22). Fumarolic-hot spring research

indicates that the transfer of many elements by hot meteoric water is a major process. It yet cannot be disproved that some ore metal present in the walls cannot be so transferred. The now conventional and current theory that ore liquids are the agents and are derived from a magma has great appeal. As will be discussed later there are difficulties in applying this hypothesis to the "epithermal" deposits without modification. The volcanic emanations, whatever their *ultimate* source, may be a major factor in the origin of the "epithermal" deposits. A telluric source for the magmatic fluids or volcanic emanations—they may be the same thing—appeals to some (Holmes, 8; White, 23; Schmitt, 16). The ore magma hypothesis of Spurr (21) encounters many serious objections well known to most students. Particularly, the need for homogeneity is violated by the great variation in the character of a given vein. "Floating" breccia can be explained as relict fragments of breccia formerly in a gouge matrix. The gouge is replaced by vein minerals. Another explanation is that the fragments touch, but do not appear to do so in sections.

Fenner, Allen and others have pointed out that it may be difficult to distinguish ore deposits precipitated directly from the gaseous phase from those from a liquid phase. At Katmai sulphides were deposited at the surface from the gaseous phase. Some geochemists would favor a theory of origin that would emphasize deposition of ore deposits, or at least some ore deposits, in this manner.

Relationship to Hot Spring-Fumarolic Phenomena.—The fundamental research on volcanoes, fumaroles and hot springs made largely in the first and last few decades of the hundred years just past is reviewed by the writer in a recent paper (19). This work by several score of brilliant volcanologists, geophysicists and chemists resulted in the following conclusions:

1) The volcanic emanations are the universal motivation for volcanic, fumarolic, hot spring and geyser activity. They are characterized by superheated steam and much smaller quantities of CO_2, H_2S, NH_3, CH_4, HCl, HF, NaCl, and NH_4Cl. In some cases they are accompanied by the ore metals. Temperatures may range up to incandescence; pressures up to hundreds of atmospheres.

2) Meteoric water comprises most of the water in the hot spring and geyser systems, and in places is important in fumaroles.

3) The emanations may emerge at the surface practically unchanged, but where meteoric water is dominant they are quenched and absorbed in depth.

4) The steam never could have been in contact with an excess of liquid water from the time it gained its superheat.

5) Fumarolic phenomena show that the ore metals are transferred in the gas-vapor-sublimate stage. Hot spring waters are known to carry the metals also.

6) Geophysicists insist that there is no known force capable of raising liquid water from a deep-seated magma to the surface of the earth. Conversely, surface water, unless it encounters superheated steam in excess, should penetrate the earth for great depths so long as openings of adequate magnitude are available.

At Yellowstone Park, where the alteration of the rhyolite-dacite walls has been carefully studied by surface observation and core drilling, several types of alteration and their relationship in space and time are well known. In general a beidellite-type clay results from approximately the first encounter of H_2CO_3 charged hot spring water with the silicates of the walls. The tendency is to remove all the alkalies, alkaline earths and some of the silica and thus to leave an "inert" clay composed of alumina, silica and water. This is here called the "carbon dioxide-leaching" phase. The effluent liquid from this reaction is charged predominantly with the alkaline and alkaline earth bicarbonates and colloidal silica. It seems to be over-saturated with potash and silica and the "farther out" metasomatism shows an increment of potash, in part by base exchange in the feldspars, with a corresponding loss of soda to the liquid. This is here called the "potassic" phase. It is marked at Yellowstone Park by the development of a quartz-orthoclase alteration. The effluent liquid from this is saturated with soda and silica. The next phase then is sodic and still silicic. Orthoclase then gains soda by base exchange and zeolites and calcite are stable and are deposited. This is here called the "sodic" phase.

Quartz seems to be stable in all the phases or zones "beyond" the beidellite-type clay phase with the metacolloids more prominent in the more distant zones. *Calcite* does not appear to be stable until much of the H_2CO_3 is neutralized by reactions or lost by lower pressure. At Yellowstone Park and at Steamboat Springs it is deposited characteristically under alkaline conditions. It tends to choke up the near surface openings.

The conclusions of geophysicists, and results of the fumarolic-hot spring studies, seem to have important implications *when it is assumed* that the environment during the formation of the "epithermal" deposits is the same as that observed in modern fumarolic-hot spring areas. This assumption is one that has been supported by many from Elie de Beaumont to Waldemar Lindgren. It may be objected here that uniformitarianism may be pushed too far. Thus Tertiary volcanism with its accompanying "epithermal" deposits seems to have been on a larger scale than Quaternary and present day volcanism. This objection, however, may be valid only on the basis of scale and not on quality.

It is well established in the hot springs areas that, where H_2S is in excess near the surface, oxidation may produce sufficient sulphuric acid to neutralize and to make acid the normally alkaline spring water. This results in an alteration of the walls characterized by the kaolinite group clays, the sulphates particularly alunite, and often massive silicification. Like the beidellite type of clay alteration, the alkalies, alkaline earths and much of the silica are taken into solution and "inert" clay left. Much silica seems to be redeposited as shallow silicification. Some of the "epithermal" deposits show a marked analogy to the above system. Goldfield, Nevada, is the type example.

The Yellowstone Park studies indicate a moderately complex circulation of meteoric water and volcanic emanations. The meteoric water appears to dominate the larger openings. The "gases" may be encountered near the surface even where the country rock is largely flooded by surface water. It is conceivable that the complexity of the structure of the country rock in "epithermal" districts may result in intricate and unique paths of circulation. The major

fissures may serve both as an entrance and exit of the meteoric waters. Circulation *from the walls to the veins* may be common.

Ionic interchange must be important as demonstrated at Butte, but the convection process must often dominate as an effective agent of transfer. The alteration zones doubtless migrate, even if the areas dominated by meteoric water do not change in position, for when a clay zone, for example, approaches inertness the then unmodified fresh solutions would attack previously but differently altered zones farther along.

Wall rock alteration seems inadequately described for many important "epithermal" districts. But see Lovering (12), Burbank (3, 4) and Butler (5). It presents a confusing picture when compared with the clear-cut Yellowstone Park phenomena. Tentative conclusions are: that the "primary" clay alterations in some, perhaps many, cases must have been overlooked; that the potassic and sodic alterations affect both the walls, the selvage of the veins, and that their characteristic minerals also are deposited in the veins; and that the primary argillization should progress "forward" and replace earlier zones of the potassic and sodic phases.

As for the ore metal phase of the "epithermal" deposits, the volcanic gas-vapor-sublimates or emanations seem wholly adequate as agents for the transfer of the metallic elements to the meteoric water shell. These elements are known to be, and to have been, associated with the emanations at many places. The Yellowstone Park hot alkaline spring water with abundant NaCl and Na_4HCO_3 is a type common to volcanic areas and in some regions contain small quantities of the ore metals. Similar waters at Steamboat Springs, Nevada, carry mercury, arsenic and antimony in small quantities and the older sinter contains cinnabar and stibnite. Sludges in these springs contain "commercial" gold with mercury, antimony, silver and copper.

Ore Mineral Phase.—Sales and Meyer (15) indicate that the various types of metasomatisms can be going on in the walls at the same time in successive zones. In the case of the metallic minerals in the veins a requirement seems to be a change in the fluids at a given spot with them. Since the paragenesis is nearly constant from deposit to deposit, often starting with quartz, pyrite and arsenopyrite and oxides, followed by the simple sulphides, followed by the complex sulphosalts, followed by the precious metals and mercury with the gradation in order of decreasing solubility, increasing softness, etc., the final explanation must fit these established facts. Brown (1) thinks a progressive change in the source of the metallic emanation is the explanation.[4] In the system outlined a change of the ore liquid could occur, particularly in the amount and proportion of the principal salts and colloidal silica due to changes in the character of the walls through progressive alteration. The relative concentration of the chloride ion in the metal bearing water should progressively rise. W. H. Newhouse (13) shows that primary liquid inclusions in sulphides have a high saline content.[5] The abundant early quartz in the vein may be

[4] J. W. Gruner in his criticism says geologists seem not to have given mass action (molecular concentration) sufficient weight in discussing this sequence.

[5] Dahlblom (7, p. 390) observes that rocks encountered at depth, and apparently dry, contain NaCl and $CaCl_2$. The ones from the greatest depth were nearly saturated brines. These facts may explain the brines in the sulphides as being the result of the processes that affect both deep rocks and minerals and these processes may not be connected with those that form ores.

primarily related to the loss of silica during argillization. A decrease in silica is to be expected with time.

CONCLUSIONS.

A study of sixty described "epithermal" deposits excluding those in carbonate rocks and other published data indicates that:

1) Veins predominate and they generally follow faults, in many cases faults of more than 100 feet of displacement.

2) The "epithermal" or "Tertiary type" may, in fact, be largely unique to Tertiary time.

3) The cone-like or wedge-like upward flares of structure are explained as being governed by the "free-face" principle as in blasting.

4) The telescoping of mineralization variety in "epithermal" veins should not be used as examples of gradation of the standard types of deposits such as "epithermal," mesothermal, etc.

5) Wall rock alteration in "epithermal" deposits has been inadequately studied.

The hypothesis of formation of the "epithermal" ore bodies in the meteoric water shell [6] appears to simplify the explanation of several features of these deposits such as:

(a) The nearly universal shallow bottoming is explained as a factor related to the base of the meteoric water shell. In a number of districts the hypogene ore bodies have a horizontal extension many times greater than the vertical and this extension seems to follow the topography.

(b) The delicate layering of the vein minerals may be due to seasonal and longer climatic changes, *i.e.*, changes largely of quantity of water entering the meteoric water shell.

(c) The difficulty of classifying many "epithermal" minerals as to hypogene or supergene is explained as the result of the intimate mingling of hypogene and supergene environments.

(d) "Epithermal" ore bodies commonly do not outcrop, but the apex of the hypogene (?) ore is at shallow depth. This is possibly explained by the rapid change in conditions near the original surface. Such a change is evident in the hot spring areas.

SUGGESTED IMPLICATIONS.

The free silica in the "epithermal" deposits particularly if these belong to the environment postulated, can be accounted for as derived from alterations of the walls. Schwartz (20) concluded that the silica in wall rock alterations, not necessarily "epithermal," however, about balanced. This infers that new or "exotic" silica was not needed. Lindgren's examples of wall rock gains and losses (11, pp. 459–562) show silica loss in the altered wall and gain in the vein. Lovering's data (12, p. 243) and those of Sales and Meyer (15) show the same thing. It seems unnecessary to call on the magma for silica for the

[6] In this connection it was of particular interest for the writer to read Pošepný (14, pp. 17–72).

"epithermal" deposits. Knopf (9, p. 45) and Schmitt (17, p. 802) think that gains of silica in "mesothermal" quartz veins and in garnet zones can be accounted for by losses in the walls by alteration.

Such a source for the silica appears to make it less necessary on an *a priori* basis to postulate "a magma" as the source for the "epithermal" deposits. The volcanic emanations can be derived by the heating alone of many kinds of rocks. In depth this could be made effective by release of pressure. The deeper Earth shells should contain progressively more of the metals. The principles demonstrated by Zies (24) and of the chloridizing roast (Liddell, 10, p. 1178) may be adequate to account for the collection and transfer of the metals.

The many resemblances of the "epithermal" deposits to those of other classifications, particularly the mesothermal and hypothermal in non-carbonate rocks, suggests that all fit into one eclectic frame. The evidence is weak, however, that the "epithermal" deposits grade into mesothermal and hypothermal deposits in depth for the "epithermal" deposits usually show true bottoms such as wholly barren quartz and, indeed, even largely unmineralized rock breccia.

A possible outcome of the verification of a close tie in origin of the "epithermal" deposits and hot springs would be the development of guides to likely conditions in depth. It may be found that "epithermal" ore deposition is usually just above (or to one side of) the hypogene clay zone and presumably associated with a sericitic-quartz or potassic phase. If one found that one was in the zeolitic-calcite phase of wall rock alterations one might expect most of the ore shoots to be largely intact in depth, or if in the clay zone one might interpret this to mean one was near the bottom of the zone of ore deposition. The above frame may not be the general one at all, but it does seem as though this particular phase of investigation could have results of considerable utility in the exploration for ore.

A systematic field and laboratory study of the possibilities should be made. The data in the literature are inadequate.

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THE BEHAVIOR OF SOME DIABASE AND BASALT DILATION DIKES IN THE UNION COMPANION MINE, CORNUCOPIA, OREGON.

A. F. FREDERICKSON.

ABSTRACT.

At depth the path followed by the dikes in the Cornucopia Gold Mining district, Oregon, is almost independent of the minor structural features of the area. At intermediate depths the dikes "roll" into and follow planar zones of weakness (faults, veins, etc.) for a short distance, roll out of the structurally weak zones, and continue to the surface at high angles. Minor changes in the strike and the dip of these dilation dikes, when they are in the plane of a vein, result in the displacement of portions of the vein alternately to the footwall and hanging wall of the dike.

THE effects of dilation dikes on different types of veins have often been discussed in the literature.These articles are usually accompanied by some formulae indicating how much a dike of a given thickness will displace a certain vein if it transects the vein at a given angle. These relationships are shown below:

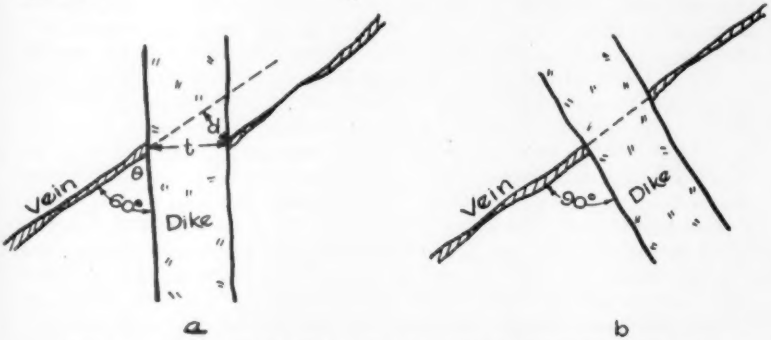

FIG. 1. The amount of displacement of a vein caused by a dilation dike cutting it at different angles.

If a dilation dike of thickness t crosses a vein at an angle of 60°, as shown in Figure 1a, it will "throw" the vein toward the footwall a distance d given by the equation

$$d = t \sin (90 - \theta) \quad \text{or} \quad d = t \cos \theta.$$

As can be seen from the sketch (Fig. 1b), if the dike crosses the vein at an angle of 90°, it only displaces the vein a distance equal to its thickness and does not cause any "throw."

The purpose of this paper is to show that in this area, although the above arithmetic is correct, the dikes rarely behave like those shown in Figure 1.

The following figures show the behavior of several large and small diabase and basalt dikes that cut and displace the Union Companion gold-quartz vein in the Union Mine located at Cornucopia, Oregon.

The exact location, attitude and thickness of these dikes, in relation to the vein, is accurately known from measurable information (location of contacts, changes of dip and strike, thickness, etc.) obtained from mine openings and diamond drill cores.

FACTORS INFLUENCING THE BEHAVIOR OF DILATION DIKES.

The Union Companion gold-quartz vein occurs in and near the "contact" of a granodioritic rock mass with a hornfels-greenstone sequence of rocks. The word "contact" is placed under quotation marks because the granodiorite, at least in this specific area adjacent to the hornfels-greenstone rocks, was not an igneous mass (implying a molten liquid or a molten "mush" consisting of a liquid melt and crystals) but was a product of metasomatism. The "contacts" between the greenstone-hornfels rocks and the granodiorite are gradational rather than sharp. Complete transition from one rock type to the other can be observed in many places in the area both on the surface and underground. In places large masses of granodiorite occur as isolated blebs in either the hornfels or greenstone host rocks. The granodiorite is structurally a much stronger rock than either the hornfels or greenstone and fractures persist for great distances in it. In contrast, the hornfels and especially the greenstone tends to crush rather than to develop strong shear zones. Analogous to the bending of light as it passes from a dense to a less dense medium, the fractures change in direction when they pass from the granodiorite into the less competent rocks where the fractures break up into a series of stringers or disappear in a crush zone. The zone of maximum crushing and movement on a small scale has occurred at these transitions between the granodiorite and hornfels-greenstone rocks which is often quite irregular. The realization that large isolated masses of granodiorite can develop in the greenstone rocks which effect the strike and dip of the fissure zone containing the quartz vein that passes through this transition zone is a valuable practical concept. In this mine, the transition zones near the vein are badly broken up, consequently exploration drifts and raises in them are expensive. Knowing the physical character of the rock that results as the vein passes from one rock type to another enables the geologist to plan a development program (and let development contracts) in a more efficient manner than would be otherwise possible.

The quartz veins in this area are quite extensive. Some of them can be traced along their outcrop for over 6,000 feet and are known to extend at least 2,500 feet below their outcrop. Only a few of these veins, however, have proved to contain enough sulfides and gold to be considered as ore deposits.

Where the veins are observed in the granodiorite, they mostly persist for great distances and are quite regular in both strike and width. The veins found in the greenstones and hornfels are quite erratic in strike, dip, and width.

In no case has a mine been developed at a location consisting exclusively of one rock type or the other. Only where the veins have developed in an area where both rock types are present has enough small scale, recurrent movement taken place to produce enough brecciation to provide suitable channels through which the later ore solutions traveled and deposited the minerals that made those portions of the vein minable.

The recurrent movement on a small scale that microbrecciated the quartz veins also produced sheeting and jointing in the country rocks. The development of these planar elements in both the quartz veins and the country rock

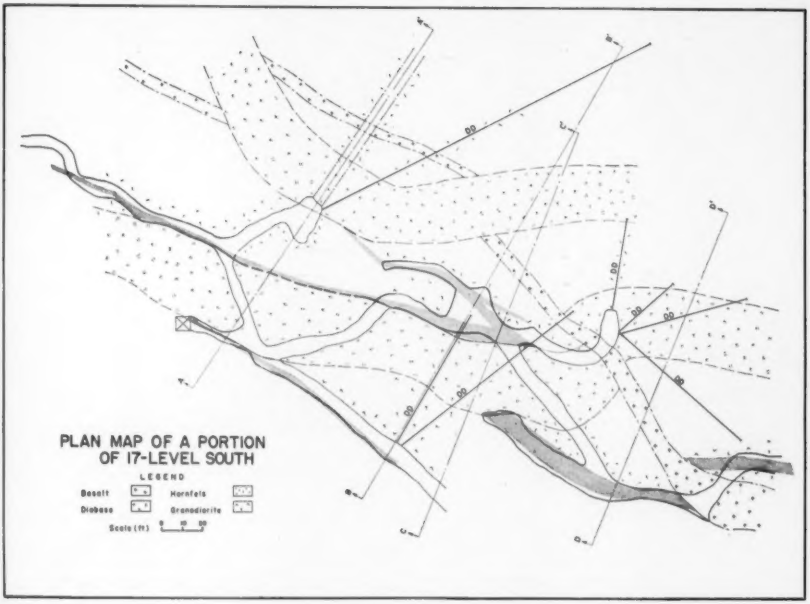

FIG. 2.

has also strongly influenced the behavior of the large and small dikes observed in this area. The following relationships between dike behavior and sheeting have been observed:

1. In a homogeneous rock type, at relatively great depths, the dikes are seldom affected by sheeting or jointing. At great depths, the dikes only change their strike, dip or thickness in a gradual manner.

2. At intermediate depths the dikes are strongly influenced by any planar element in the rocks. If a dike comes up under a strong break (a quartz vein along which movement has occurred, a strongly sheeted zone, a sharp "contact" between rock types having different physical properties, or a fault zone) the dike generally rolls into the plane of the zone of weakness, follows in this

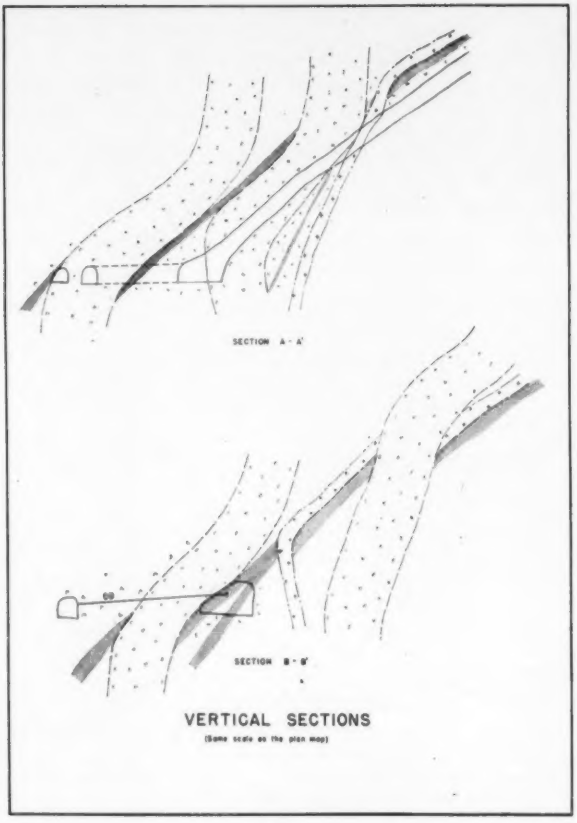

FIG. 2a.

direction for a short distance, and then rolls out and continues on its journey to the surface at a relatively steep angle. Only where the dikes encounter zones of great weakness do they travel more than a few hundred feet at low angles (under 35 to 50 degrees). In the zones of weakness, particularly at the points of entry and departure, the strike, dip, and thickness of the dike often changes rapidly.

Even large dikes, 50 to 90 feet wide, vary greatly in thickness, dip, and strike in structurally weak zones. The larger dikes, however, commonly exhibit these variations only locally, whereas the small dikes may follow these zones for much greater distances. The tendency for small dikes to follow fault zones complicates underground structural problems because the optalic or

baking effects of the dike often obliterate any evidence of fault movement or alteration.

3. Closer to the surface the dikes tend to lose their ability to crosscut strong regional structural patterns except where they cross them at high angles.

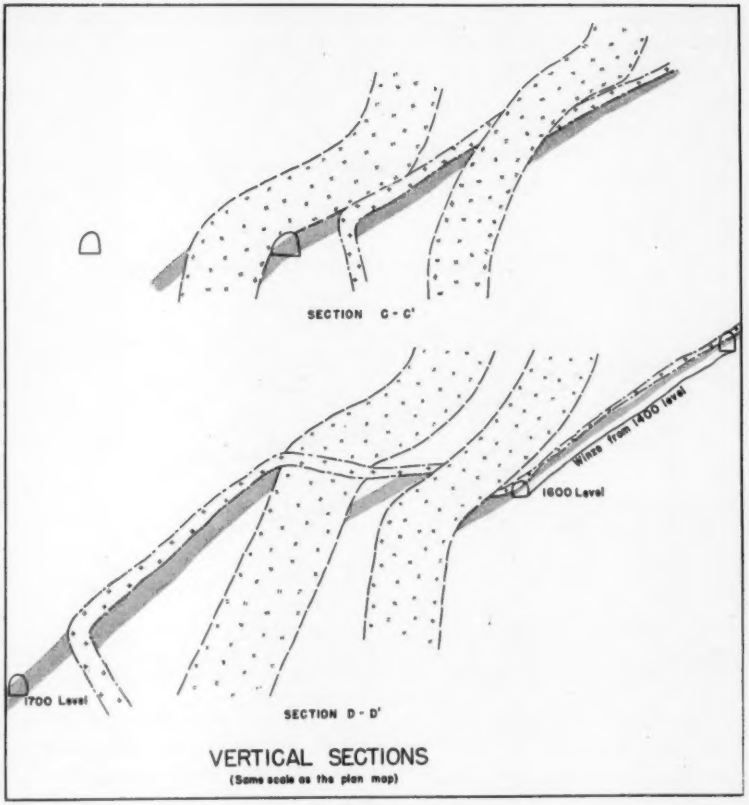

FIG. 2b.

Figure 2 is a plan of a portion of the 1700 level of the Union Companion mine. Two large diabase and one small basalt dike displace a vein which splits into several stringers at the "contact" zone between the hornfels and the granodiorite country rock. Both of the diabase dikes show sharp changes in strike and dip as they "roll" into the plane of the vein. These dikes remain in the plane of the vein for only a short distance and soon roll out to continue to the surface at a steep dip.

The small basalt dike is strongly influenced by both the structurally weak zone in which the quartz vein developed and the first diabase dike. As can be observed in the cross sections, it changes its upward path in an abrupt 90 degree angle and even doubles back on itself (see especially section D – D'). In spite of these local changes in dip, it shows only minor variations in strike. As can be observed in the lower right-hand portion of Figure 2, the basalt dike rapidly changes in thickness as it passes through the vein. The flatter the zone of weakness the more likely it is to affect the thickness of the dike.

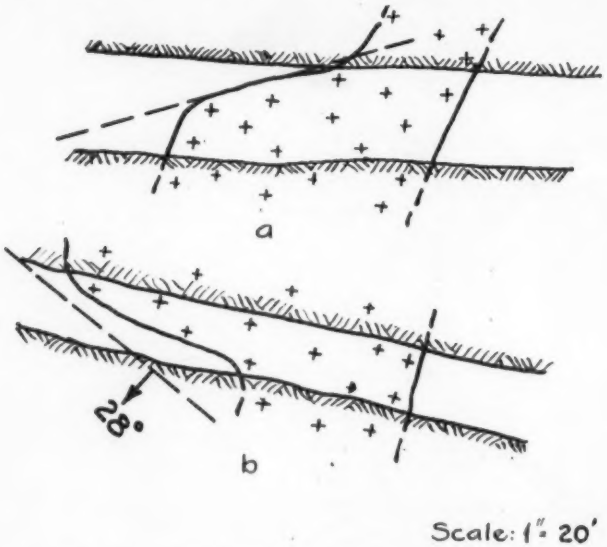

FIG. 3. Rapid change in thickness of a dike encountering a flat-lying shear zone. a. Side elevation; b. Plan view.

Figure 3 is a sketch illustrating the effect of a strong, flat-lying break on the thickness of a diabase dike observed in the Clark Extension adit in the Cornucopia district. In a distance of less than 6 feet, the thickness of the dike has been reduced from 40 to about 16 feet. Whether or not this dike widens again as it breaks through the flat-lying shear zone is not known. In the upper portion of the Union Mine another cross-cutting dike affected in this manner has been reduced from a thickness of 38 feet to a thin ribbon 3 inches wide in a distance of 85 feet. In general, these flat-lying shear zones act much like the orifice on a container used to extrude frosting onto a cake. As the dike passes the "orifice" it is sharply reduced in size and often wanders, in a sinuous manner, along an erratic course until it pinches out.

ECONOMIC ASPECTS OF DIKE BEHAVIOR.

For the following reasons, a knowledge of the behavior of dikes of this type is necessary in order that an economical development program be set up to exploit those portions of a mine in which these dikes occur:

1. The focus toward which several dikes tend to converge is usually a zone of structural weakness in which ore shoots have developed. The recurrent movements within a quartz vein which localized the sulfides or gold in an ore shoot usually develop strong planes or zones of weakness in the country rocks which influenced the behavior of the dikes that crossed these zones at a much later date. For this, and other reasons, high grade ore is often found near these dike intersections.

2. After dikes have rolled into the plane of a vein they often undulate in a sinuous manner along the strike and also gently roll up and down in the dip direction. In this manner they wander from the hanging to the footwall por-

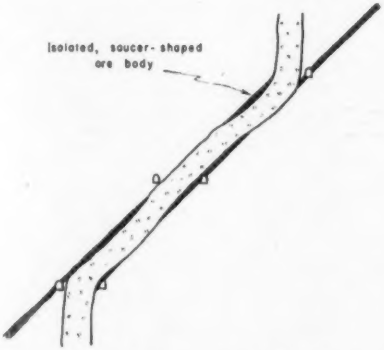

FIG. 4. A portion of the Union Companion vein illustrating how a dike undulated in the plane of a vein and alternately threw portions of it to the hangingwall and footwall. (Not drawn to scale.)

tion of the vein and frequently isolate saucer-shaped portions of high-grade ore. For example, a large diabase dike, having essentially the same strike as the vein, rolled into the Union Companion vein in the upper portion of the Union Mine. This dike stayed in the plane of the vein for over 500 feet along the dip and almost 1,200 feet along the strike. The dike stayed on the footwall of the vein for a short distance, then rolled into a shear zone in the middle of the vein, and finally rolled into the hangingwall shear zone where it stayed until it rolled up into the country rock. In one portion of the mine, however, the dike rolled down from the hangingwall almost to the footwall of the vein before it rolled back into the country rock above the vein as illustrated in Figure 4. The quartz vein also varied in thickness so it was believed that the dike had stayed in the hangingwall and that the vein had narrowed in this particular spot. When drawings were made to eliminate graphically the influ-

ence of the dikes, and the configurations of the ore were plotted, a blank spot was observed in the middle of a high-grade ore shoot. Subsequent diamond drilling located this high grade, saucer-shaped ore body that had been overlooked for many years.

Figure 5 shows a portion of the north section of the Union Mine. The small dikes are strongly influenced by the planar elements in the rocks. One small dike came up a fault and completely obliterated any evidence of alteration

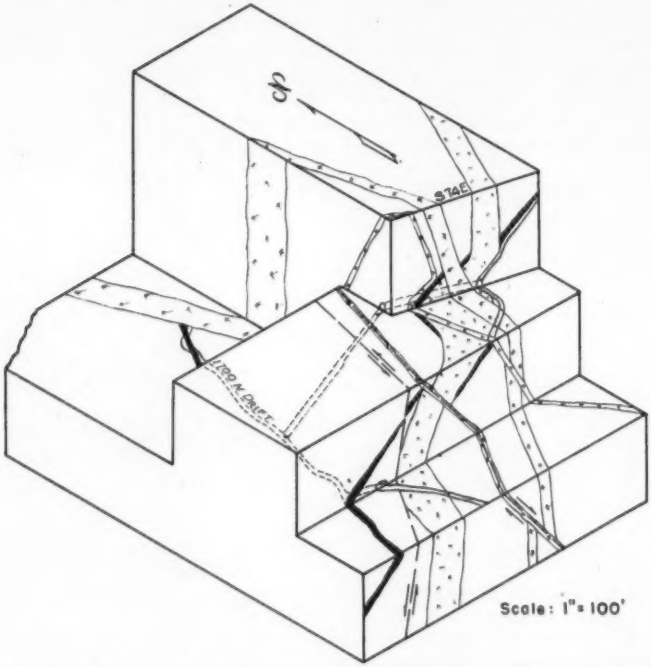

FIG. 5. Block diagram of a north portion of the Union Mine showing the influence of dikes on the vein.

adjacent to the fault plane. The other small dike, although it maintained approximately the same strike, reversed its dip for a short distance when it rolled into the hangingwall of the vein.

SPECIAL MAPPING PRECAUTIONS.

Care must be used when mapping an area known to contain dikes occurring in hornfels country rocks because these rock types cannot be easily distinguished on the basis of hand specimens alone. Although these rocks tend to

develop different joint patterns, enough variation exists in these patterns to make jointing a poor criterion to use to identify these two particular rock types.

Dikes as wide as 80 feet commonly have glassy contacts only one-quarter of an inch in thickness; therefore great care must be exercised in order not to overlook the dikes, especially in old mine workings where the rock surfaces are seldom clean. Because it is sometimes almost impossible, from a practical standpoint, to clean up rock surfaces in old drifts, roughly ground thin sections made from rock chips taken at carefully selected intervals and examined with a petrographic microscope often yield required answers in a much shorter time than the laborious cleaning techniques.

CONCLUSIONS.

The application of the observations presented here concerning the behavior of dikes to several portions of the Union Companion Mine that had been abandoned for many years led to the discovery of a high grade ore body. Familiarity with the behavior of these dikes greatly simplified the development work in areas where these dikes occurred.

These simple observations applied to other districts known to contain dilation dikes of this character will undoubtedly yield information leading to the discovery of ore bodies that have been overlooked when the property was first developed.

An attempt to reconstruct the shape of the vein system and the ore shoots in it by graphically eliminating the dilation effects of the dikes also yields information that may result in the discovery of an ore body.

ACKNOWLEDGMENTS.

Mr. H. Ferrel Anderson and Mr. J. E. Dunn, respectively geologist and chief engineer, gathered and plotted most of the data from which the drawings and this discussion were derived. Their excellent engineering and geological work contributed greatly to the success of the underground development and exploration program when these difficult dike problems were encountered.

GEOLOGY DEPARTMENT,
WASHINGTON UNIVERSITY,
ST. LOUIS 5, MO.,
Aug. 24, 1949.

GROUND-WATER PROBLEMS IN THE PHILADELPHIA AREA [1]

JACK B. GRAHAM.

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ABSTRACT.

Large quantities of ground water are used by the Philadelphia Naval Base and many industries in south Philadelphia, as well as by municipalities near Philadelphia in both Pennsylvania and New Jersey.

The areal contact between unconsolidated sand, gravel, and clay strata of the Atlantic Coastal Plain and consolidated rocks of the Piedmont province extends in a northeast-southwest line through central Philadelphia. This line of contact, the so-called Fall Line, sharply separates the area of highly productive sand and gravel aquifers of the Coastal Plain from the less productive bedrock aquifers of the Piedmont Plateau.

The daily withdrawal of ground water from sand and gravel in the Philadelphia area, including Bristol, Pa., and Trenton, N. J., is approximately 110 million gallons. Wells around Philadelphia yield an additional 13 million gallons a day from consolidated rocks of the Piedmont province. The Raritan formation of Cretaceous age is the principal aquifer for wells in south Philadelphia and the adjacent Camden area. The large quantity of water pumped and the limited extent of this aquifer in the area provide a potentially serious interstate water problem. Ground-water levels in the strategically important Naval Base area have not declined seriously as yet, but increasing withdrawal planned in adjacent New Jersey is expected to lower water levels in south Philadelphia.

The Delaware and Schuylkill Rivers are believed to be the chief sources of recharge to the Raritan formation, even though heavy pumping on either side of the Delaware River may be expected to affect water levels on the other side. Recharge appears to be adequate generally for present rates of withdrawal, but further studies are needed for an evaluation of the safe maximum yield of the area.

The chemical quality of ground water pumped from the Raritan formation is satisfactory for most purposes, but periodic analyses indicate that the concentration of dissolved solids is increasing. This deterioration

[1] Published by permission of the Director of the U. S. Geological Survey.

of the chemical quality probably is due to the character of the water and bottom sediments of the Delaware and Schuylkill Rivers. Shallow aquifers in south Philadelphia contain large amounts of gases generated by the decay of river silts and city refuse occupying low areas.

The States of Pennsylvania and New Jersey, together with the municipalities concerned, are coordinating their efforts for a practical solution to the ground-water problems of the Philadelphia area.

INTRODUCTION.

THE city of Philadelphia, which is coextensive with Philadelphia County, lies in the extreme southeastern part of Pennsylvania. The city has an area of about 135 square miles and a population estimated to be 2,125,000 as of 1948. The municipal water supply is obtained from the Delaware and Schuylkill Rivers at intakes that lie within the city limits. The Schuylkill enters the Delaware at League Island in south Philadelphia. This river is tidal to Fairmount Dam in central Philadelphia, a distance of 7½ miles above the mouth. The Delaware River is tidal to Trenton, N. J., a distance of 38 miles above League Island. Both rivers are fresh at Philadelphia.

The use of ground water within Philadelphia is confined largely to industries, the Philadelphia Naval Base being the only place where ground water is used for potable as well as industrial supply. In suburban Philadelphia and in bordering areas in New Jersey, however, ground water is used extensively for both municipal and industrial supplies.

GENERAL GEOLOGIC FEATURES.

Philadelphia is situated on the so-called Fall Line, which is the line of contact between the crystalline rocks of the Piedmont province to the northwest and the unconsolidated clay, sand, and gravel forming the Atlantic Coastal Plain to the southeast. This contact between the crystalline rocks of the Piedmont and the Coastal Plain sediments extends through central and southwestern Philadelphia in a general northeast-southwest direction. As indicated by Figure 1, only about a quarter of the city of Philadelphia is underlain by unconsolidated clays, sands, and gravels of the Coastal Plain formations.

The Piedmont physiographic province is underlain chiefly by Precambrian crystalline igneous and sedimentary rocks, which have undergone considerable metamorphism. The igneous rocks include granite, diorite, monzonite, and gabbro. The metamorphic rocks include gneiss, schist, quartzite, marble, slate, and serpentine. In areas immediately to the north and west of Philadelphia there is a thin belt of Paleozoic (Cambrian and Ordovician) limestone, beyond which is a wide belt of Triassic sandstone, shale, and diabase or "trap rock." Suburban Philadelphia extends into the Piedmont province and will be considered a part of the Philadelphia area as described in this report.

GROUND WATER.

Water-Bearing Properties of the Consolidated Rocks.—Many of the industries in Philadelphia are situated in those parts of the city underlain by

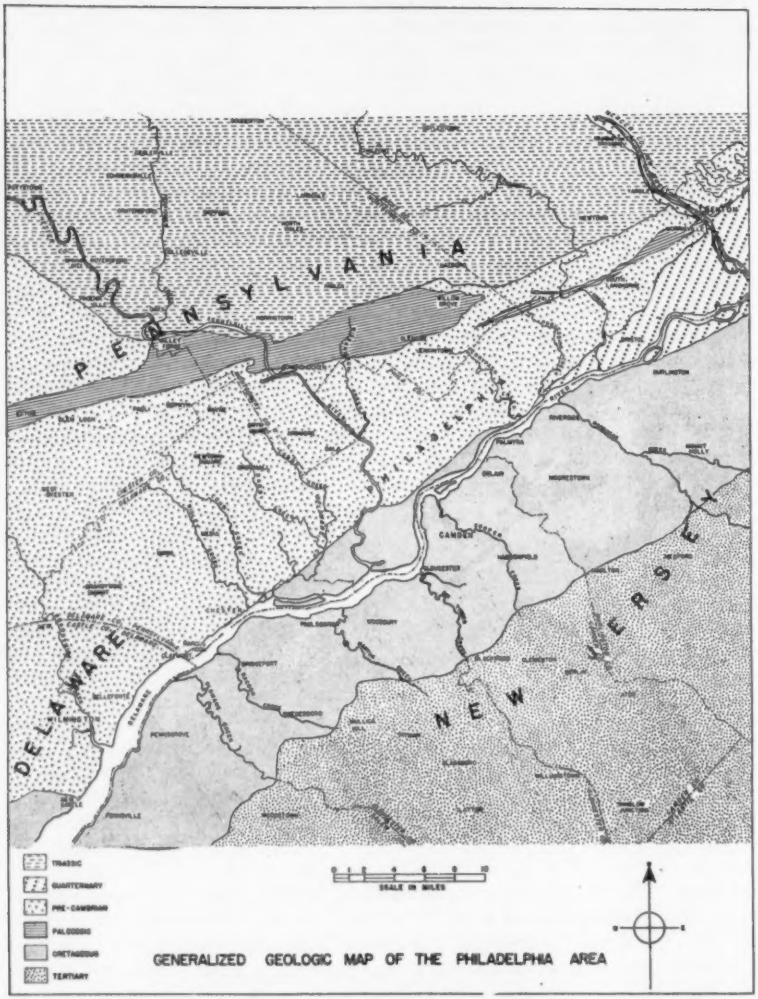


FIG. 1.

crystalline rocks of the Piedmont province. For this reason, highly industrialized northeast Philadelphia and other such sections in north and west Philadelphia are fortunate with respect to foundation conditions but are less fortunate with respect to the availability of large supplies of ground water

suitable for industrial processing and cooling needs. Many wells have been drilled into the consolidated rocks by industrial and manufacturing concerns in Philadelphia in an effort to obtain satisfactory ground-water supplies, but few attempts to obtain large supplies have been successful. In the area of crystalline rocks there has been a tendency to space wells close together, and in the past many excessively deep wells were drilled in the hope of passing through the relatively unproductive schist and gneiss, which predominate in the area, to reach more favorable aquifers. Many of the older industrial wells have been abandoned, and the water needed for industrial purposes has been obtained chiefly from the City Bureau of Water. Records of about 425 wells drilled into the gneiss, schist, granite, and related consolidated rocks in Philadelphia indicate an average yield of about 46 gallons a minute, which is quite high for rocks of this type. A statistical study of these records indicates that the yield ranges from 1 to 500 gallons a minute, and the depth from 36 to 2,031 feet. The records of most wells do not report the depths at which major water-bearing openings were encountered, so that the relation of yield to total depth of wells probably is not an accurate determination of the relation of yield to depth of inflow. All rock wells in Philadelphia, however, have been classified according to depth, and it appears that the most favorable opportunities for maximum yield occur in the first 300 feet of drilling. Though a number of wells have been drilled much deeper in Philadelphia, several to more than a thousand feet, it is believed that relatively few openings occur below 500 feet.

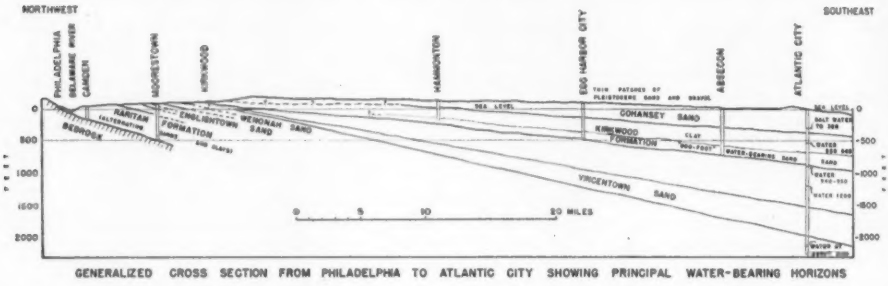
Wells drilled in the narrow belt of Paleozoic limestone north and west of Philadelphia are typical of limestone wells in general; that is, they range from dry wells to wells of large yield, depending upon the chance intersection of water-bearing joints and solution openings. This limestone belt is particularly cavernous in the Conshohocken area, and wells and springs of that locality provide the largest yields obtained from consolidated formations in the Philadelphia area.

The Triassic sandstones and shales bordering the limestone belt on the north and west generally provide adequate ground-water supplies for municipalities and industries. These sediments constitute the Newark group, which has been subdivided into the Stockton and Lockatong formations and the Brunswick shale, in ascending order. The Stockton formation, composed predominantly of fine sandstones, is the most productive of the Triassic formations. The yield of municipal and industrial wells in the Stockton ranges from a few gallons a minute to more than 400 gallons a minute. The Lockatong formation is composed predominantly of dense dark shales, and usually yields only enough water for domestic requirements. The youngest Triassic formation, the Brunswick shale, yields sufficient ground water for municipal and industrial use in some localities. Extensive areas of the Triassic sediments have been intruded by sills and dikes of diabase. These areas are the least favorable for ground-water development, in some cases the yields of wells penetrating the diabase being insufficient for even domestic requirements.

The quality of ground water is generally satisfactory throughout the area of consolidated rocks in and near Philadelphia. No serious conditions of

salt-water contamination have been reported. Hardness, iron, and manganese in most cases are sufficiently low in concentration for the water to require no treatment or to be within the range of economic treatment.

Water-Bearing Properties of Coastal Plain Formations.—From their farthest inland outcrop, along the Fall Line, the Atlantic Coastal Plain sediments extend southeastward from the Philadelphia area to and beyond the present southern New Jersey coast. In the Philadelphia area, the crystalline bedrock floor has a dip of approximately 60 feet to the mile in a southeasterly direction. The overlying unconsolidated sand and gravel strata are believed to thicken coastward, so that the youngest Coastal Plain formations have a more gentle dip than the older sediments (Fig. 2).

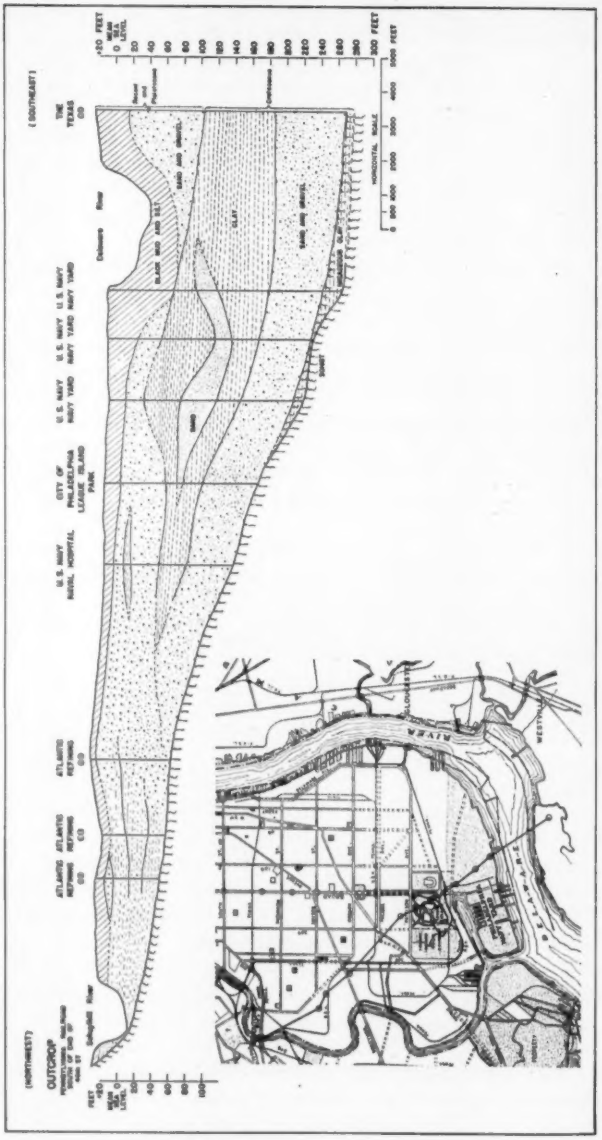


GENERALIZED CROSS SECTION FROM PHILADELPHIA TO ATLANTIC CITY SHOWING PRINCIPAL WATER-BEARING HORIZONS

FIG. 2.

The Coastal Plain formations crop out in relatively narrow bands roughly parallel to that part of the Delaware River between Camden and Trenton, the older beds being exposed along the Delaware River and the younger formations in bands successively nearer the Atlantic Coast. Only the lowermost, the Raritan formation of Cretaceous age, is known to occur on the Pennsylvania side of the Delaware River. This formation underlies part of south Philadelphia and may occur in deeper parts of the Delaware River Valley along the Pennsylvania border north of the Philadelphia-Camden Bridge. In the New Jersey area adjacent to Philadelphia, the Magothy formation, also of Cretaceous age, overlies the Raritan, but the two formations are not easily distinguished and in many wells it has not been possible to recognize the subsurface contact.

The Raritan formation is predominantly a light-colored complex of sand, gravel, and clay, the most diagnostic feature being a red or red and white variegated plastic clay used extensively in the outcrop area by the ceramic industry. The basal part of the formation is characteristically coarse-grained, in some places being composed of coarse gravel and cobbles. Owing to the irregularities of the crystalline bedrock floor and variable conditions of deposition, the lithology of the formation changes markedly from place to place. In south Philadelphia the bottom of the Raritan is encountered in wells at a



GEOLOGIC SECTION SHOWING THE OCCURRENCE OF WATER-BEARING SANDS AND GRAVELS ALONG A LINE FROM THE SCHUYLKILL RIVER NEAR GRAYS FERRY AVENUE BRIDGE IN PHILADELPHIA, TO WESTVILLE, NEW JERSEY

FIG. 3.

maximum depth of 300 feet, but such depths occur only in pre-Cretaceous valleys incised in the bedrock, as in the vicinity of the Naval Base.

The Magothy formation, which lies at the surface in the Camden area, is composed, like the underlying Raritan, of alternating beds of sand, gravel, and clay, but it includes some darker lignitic and glauconitic material. The maximum known thickness of the Magothy and Raritan formations together, in the Camden area, is about 240 feet, and in the Camden well fields that lie north of the city the thickness is somewhat less. Younger Cretaceous and Tertiary sediments of the Coastal Plain crop out east of the area under discussion and will not be described further here.

Overlying the Raritan and Magothy formations in the Philadelphia area are Pleistocene and Recent sediments laid down by the Delaware River and its tributaries. Although these Quaternary silts, sands, and gravels have a thickness of 100 feet or so in the valley of the Delaware, they have not been extensively used as sources of ground water because of the presence of the more productive formations beneath. The one exception is the Bristol area, northeast of Philadelphia, where Pleistocene and Recent gravels are being widely utilized for ground-water supplies.

The relationship of the Cretaceous and Quaternary water-bearing sands and gravels of south Philadelphia is illustrated by a section that extends down the dip from the Fall Line near the University of Pennsylvania to Westville, N. J. (Fig. 3). Wells in an irregular band along the Fall Line in south Philadelphia derive water from Pleistocene sands and gravels containing water under water-table conditions. Southeast of the truncated edge of the plastic clay of the Raritan formation, indicated in the cross section, most wells utilize the basal gravel of the Raritan formation. This aquifer provides the major part of south Philadelphia's ground-water supply. The larger municipal and industrial wells in adjacent New Jersey also utilize, for the most part, the basal gravel of the Raritan. Recent borings and water-well test data indicate that considerable ground water is available from shallow Pleistocene sediments in south Philadelphia, but no extensive use of this supply has been made to date. This lack of use is due partly to the better chemical quality of water in the deeper gravels. The preference for the sands and gravels of the Raritan for ground-water supply both in south Philadelphia and adjacent New Jersey provides a potentially serious interstate water problem, particularly because the areal extent of this aquifer in the Philadelphia area is relatively small in relation to the quantity of water pumped.

USE OF GROUND WATER IN THE PHILADELPHIA AREA.

Current production of ground water from the Raritan formation in south Philadelphia totals approximately 30 million gallons a day. Most of this quantity is used by manufacturing industries, as shown in the following table:

Table of Industrial Ground-Water Use in Philadelphia

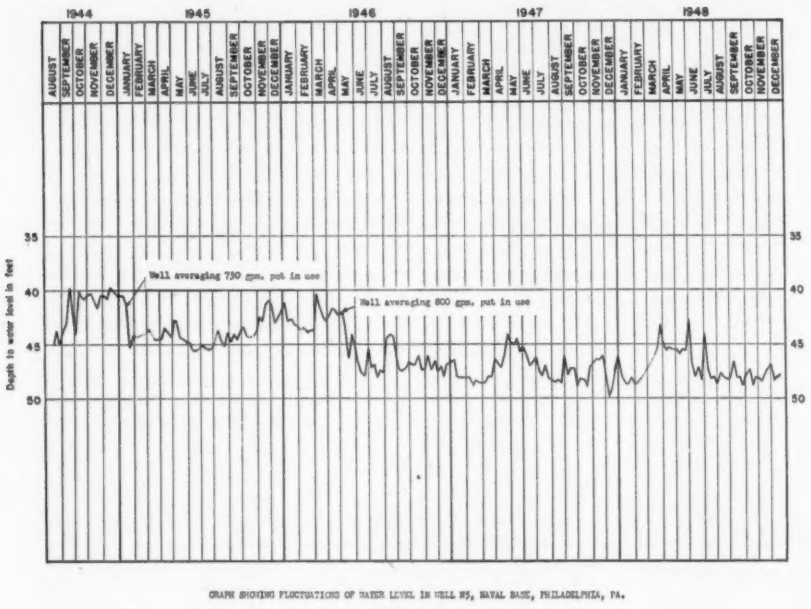
Type of industry	*Million gallons a day, 1947*
Distilling	7.1
Shipbuilding	3.8
Air conditioning	3.5
Ice making and cold storage	2.6
Chemical manufacturing	2.5
Aircraft assembling	1.5
Dairying	.8
Metal working	.6
Railroading	.5
Rubber manufacturing	.5
Food processing	.3
Meat packing	.3
Oil refining	.3
Miscellaneous	4.5

In New Jersey, the municipal requirements of the city of Camden amount to about 23 million gallons a day; neighboring municipalities use an additional 17 million gallons a day. Although an industrial inventory has not been completed, it is estimated that industrial use in the Camden area is on the order of 30 million gallons a day. Thus total withdrawal from the Raritan and Magothy formations in the Philadelphia-Camden area is believed to be about 100 million gallons a day. The daily withdrawal from wells drilled into the Precambrian igneous and metamorphic rocks of the Piedmont province in the Philadelphia area is about 5 million gallons. Approximately 8 million gallons a day is obtained from the Paleozoic and Triassic rocks underlying suburban areas to the northwest. Municipal and industrial wells in the Bristol area, east of Philadelphia, derive about 11 million gallons a day from Pleistocene and Recent sand and gravel. Thus, according to present data, nearly 125 million gallons of ground water is being pumped daily from industrial and municipal wells in the Philadelphia-Camden area, and a large part of this quantity is derived from one formation, the Raritan.

Quantitative Problems.—The importance of ground-water supply to the industries and municipalities of the Philadelphia area emphasizes the need for an evaluation of the dependability of this resource. The reservoir volume of the principal aquifer is small in relation to the amount of water being withdrawn at present rates. It is estimated that at the prevailing rate of discharge the Raritan formation underlying Philadelphia and Delaware Counties in Pennsylvania would be dewatered completely within 5 years if there were no recharge. There can be no doubt, however, that recharge of large order is effective, as shown by observations of water-level fluctuations that have been in progress in south Philadelphia since late 1943 (Fig. 4). The graph of water-level fluctuations in an observation well in south Philadelphia indicates that no consistent downward trend in the area as a whole is apparent to date; the net decline shown by the graph is due to increase in pumping at the Naval Base itself. However, discharge may be exceeding recharge along the Dela-

ware River in the southeastern and southern parts of the city where there are localized areas of heavy pumping.

At the present time the conditions of ground-water recharge in the Philadelphia area have not been definitely established. Recharge that normally would occur from precipitation is intercepted to a large extent by the municipal sewerage system. Undoubtedly, the Delaware and Schuylkill Rivers provide much of the recharge to the ground-water supply, but the location of the chief areas of river infiltration and the amount of such infiltration have not been



GRAPH SHOWING FLUCTUATIONS OF WATER LEVEL IN WELL #5, NAVAL BASE, PHILADELPHIA, PA.

FIG. 4.

determined. Borings and well logs indicate that in a zone near the Fall Line the channels of the two rivers are cut into the basal gravels of the Raritan formation, or into Pleistocene and Recent gravels that are connected hydraulically with the gravels of the Raritan. At such places, recharge will be effective in proportion to the difference in head between upper and lower gravels and the coefficient of transmissibility of the gravels. In most of south Philadelphia, water levels in operating wells are considerably below mean river level. The coefficient of transmissibility, as determined by pumping in the Naval Base area, is large enough to indicate that substantial recharge will occur in response to lowering of the ground-water level below river level. These conditions are believed to account for the major part of the recharge now taking place in the Philadelphia area.

It is believed, however, that heavy pumping on either side of the Delaware River will affect water levels on the other side. Studies are needed to determine the amount of such interference and the extent to which it is reduced by recharge from the river.

Qualitative Problems.—Although the chemical quality of ground water in the Philadelphia area is such that some form of treatment is required for most purposes, water of highly objectionable quality is encountered in very few places. The ground water is harder than the surface waters of the area and usually contains more iron and dissolved gases. In some places the pH is low, and the water is corrosive prior to treatment. Ground water obtained in areas of New Jersey adjacent to Philadelphia has no objectionable taste and,

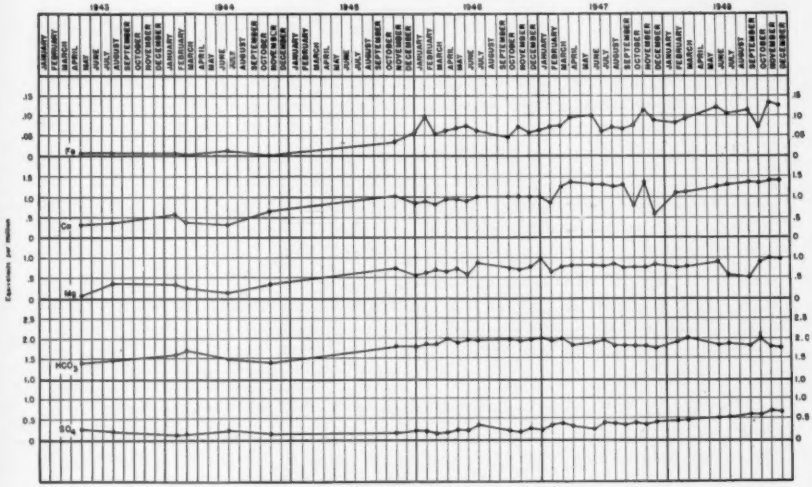


FIG. 5. Graph showing changes in the chemical character of water from well N1, Naval Base, Philadelphia, for the period 1943–48.

with the exception of a high iron content, is generally better chemically than ground water on the Pennsylvania side of the river. Periodic chemical analyses of ground water in south Philadelphia have been made for the past 4 years. In the Naval Base area the ground water is deteriorating in quality with continued use. Figure 5 shows that iron, calcium, magnesium, bicarbonate, and sulfate are among the constituents that show a slight, but persistent, upward trend. This change in the quality is believed to represent the depletion of original storage in the aquifer and the replacement of the stored water by water recharged from the river. The river-bottom silts containing coal culm, raw sewage, and industrial wastes act as a filter for the river water in the areas of recharge, and probably are the source of the increased quantities of dissolved gases and other constituents except iron. The increasing amounts

of iron in the ground water of the area are probably derived from sources indigenous to the Raritan formation, dissolved by the ground water more or less in proportion to the amount of carbon dioxide in the water. The decaying river-bottom sediments may be a source of part of the carbon dioxide.

The quality of ground water in the shallow Pleistocene and Recent gravels of south Philadelphia, in particular, is such that the water is much less suited for industrial and domestic use than water from the deeper aquifers. The condition is explained by the large area of city dumps and tidal flats lying within the zone of recharge. Much of the tideland and adjacent low areas of south Philadelphia are being filled in by city refuse. These same areas have received deposits of river silts laden with coal culm and organic material for many years. The surficial deposits in certain parts of southern and southwestern Philadelphia are so highly charged with organic material that the generation of methane and other gases is extensive. The Philadelphia Bureau of Health has reported that some of the "squatters" in south Philadelphia dump areas cook and heat with methane gas obtained by driving a pipe a few feet into the ground. Methane is generated freely in the bottom silts of the Schuylkill River, particularly during the warmer months of the year. Large blocks of loosely agglomerated river mud have been observed to rise from the bed of the river, buoyed up by the entrapped gases. Persistent bubbles of gas rising along the bulkheads and piers in the Naval Base area have been identified by Naval chemists as methane. In the summer of 1948, following the collapse of a large pier in south Philadelphia, a gas geyser erupted at the position of the fallen pier for approximately 18 hours, and at spasmodic intervals thereafter. This geyser is believed to have been caused by the release of gases from the loose river silts when they were compressed by the weight of the fallen pier.

These river silts, together with the refuse of the dump areas, constitute a filter medium for much of the water recharged to the shallow gravels, and this appears to explain the poor quality of water in the shallow Pleistocene and Recent aquifers of south Philadelphia.

NEED FOR CONSERVATION CONTROL.

It is apparent, not only from the review of conditions in the Philadelphia area but from reports on other centers of industry and population as well, that some form of conservation control of ground water should be applied wherever utilization is great and the supply limited. The State of New Jersey in 1947 enacted a ground-water conservation law and subsequently designated a strip of land along the Delaware River, including Camden and its suburbs, as a "protected area." Late in 1947 the Navy Department, on behalf of the Philadelphia Naval Base, petitioned the New Jersey State Department of Conservation to restrict new ground-water diversion planned for a large oil-refinery site across the Delaware River from the Naval Base, so that the water-supply security of the Base would not be jeopardized. At the request of the Navy Department, the United States Geological Survey conducted an investigation

in the area and reported its findings.[2] The study indicated that a new supply of 6 million gallons daily could be obtained perennially by wells at the refinery, but as a result the artesian head in the Navy well field might be expected to decline 10 to 20 feet. The State of New Jersey granted diversion rights to the refinery, subject to review after a prescribed number of years, and with the provision that pumping be postponed until the Naval Base could make pump adjustments to handle the greater lift.

This case may well be the first in which ground-water control has been applied to an interstate area. It is all the more unusual in that Pennsylvania at present exercises no ground-water control, so that the action taken by New Jersey could not be reciprocated by Pennsylvania.

INTERSTATE APPROACH TO GROUND-WATER STUDIES.

The approach to a practical solution of the ground-water problems of the Philadelphia area must be on an interstate basis. The principal aquifer occurs on both sides of the interstate Delaware River. The ground-water conditions in the area require that a thoroughgoing study be made in both the New Jersey and Pennsylvania portions of the Philadelphia area, as though the state boundary did not exist. Fortunately, Pennsylvania and New Jersey have joined with New York and Delaware to form a group of state officials charged with the duty of coordinating the development and conservation of the natural resources of the Delaware River Basin. This organization, the Interstate Commission on the Delaware River Basin, took the lead in providing for a comprehensive ground-water study of the Philadelphia area on an interstate basis. This study, initiated in July of 1949, will be conducted by the United States Geological Survey in cooperation with the respective state agencies in Pennsylvania and New Jersey concerned with ground-water matters.

U. S. GEOLOGICAL SURVEY,
PHILADELPHIA, PA.,
November 23, 1949.

[2] Graham, J. B., and Barksdale, H. C., Predicted drawdown of ground-water level at the Naval Base, Philadelphia, Pa., to result from proposed ground-water withdrawal at Eagle Point, N. J. Manuscript report in open files of U. S. Geological Survey, 7 pp., 1948.

DIFFERENTIAL THERMAL CURVES OF CERTAIN HYDROUS AND ANHYDROUS MINERALS, WITH A DESCRIPTION OF THE APPARATUS USED.

A. J. KAUFFMAN, JR. AND E. DON DILLING.

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ABSTRACT.

Investigations employing the differential thermal method of analysis have been steadily increasing during the past few years. Significant changes in the recording system have been developed mainly by replacing the camera-galvanometer type of recorder with the mechanical type and finally with the electronic potentiometer. The use of the electronic recording potentiometer has made possible and practical multiple thermal analyses. The apparatus described in this paper makes use of Brown Instrument Company electronic controller and recorder units. Details of the construction and schematic wiring diagrams are included.

One hundred and three differential thermal curves are listed, many of which do not appear elsewhere in the literature. This is the first report of a lengthy program of mineral investigation employing this method of analysis.

INTRODUCTION.

UNTIL recently most investigators employing the differential thermal method of analysis have used apparatus similar to that designed by Norton [1] and modified by Hendricks [2] and others. The camera-galvanometer recording system of this apparatus has several undesirable features, namely, the necessity of operating in a darkened room, the inability to observe the progress of the record, the inconvenience inherent in the photographic development process

[1] Norton, F. H., Critical study of the differential thermal method for the identification of clay minerals: Am. Ceramic Soc. Jour., vol. 22, pp. 54–63, 1939.

[2] Hendricks, S. B., and Alexander, L. T., Minerals present in soil colloids. I. Description and methods for identifications: Soil Science, vol. 48, pp. 257–271, 1939.

and the difficulty of making multiple records. As early as 1942 Pompeo and Penther [3] designed a "photo-pen" recorder which satisfactorily recorded differential thermal curves as well as infra-red absorption curves and the ion currents in mass spectrographic work. This seems to be the only reported departure from the camera-galvanometer recorder until 1947 when Kerr and Kulp [4] first reported their apparatus for multiple thermal analysis. Their apparatus using a Leeds and Northrup Speedomax recording potentiometer was more fully described in 1948.[5] In 1948 Herold and Planje [6] reported a new type of sample holder and mentioned their electronic recorder. Roy et al.[7] in the same year reported using a General Electric photoelectric potentiometer and A. F. Frederickson [8] mentions "a recording ammeter and an amplifier." Gruver [9] in December 1948 also mentions the General Electric photoelectric potentiometer. Rowland [10] in the same year reports using a galvanometer and a Beckman Photopen Recorder.

The use of the recording potentiometer has made multiple analyses by means of a multi-hole block possible and desirable. Kerr and Kulp, 1947 and 1948,[4, 5] have been the only ones to report on this development.

The idea of using the multiple hole block and the Brown Electronik Multipoint Recorder originated in the Research Laboratory of the Carter Oil Company, Tulsa, Oklahoma, while one of us (A. J. K.) was temporarily located at the laboratory. This apparatus, similar in principle to that reported by Kerr and Kulp,[4, 5] was developed simultaneously, but independently, at this laboratory and put into operation January 1947.

The apparatus described in this paper embodies the above principles and in addition has an improved electronic program controller regulating the heating rate of the furnace.

ACKNOWLEDGMENTS.

This problem was conducted under the general supervision of S. M. Shelton, Chief, Metallurgical Division of the Albany Branch, U. S. Bureau of Mines.

The assistance furnished by T. W. Dennis, J. F. Bayhi and H. V. Carmichael of the Carter Oil Company in designing and constructing the original apparatus is hereby acknowledged.

W. A. Phillips, engineering draftsman, prepared the drawings and illustrations.

[3] Pompeo, D. J., and Penther, C. J., Direct pen recording of galvanometer deflections: Review of Scientific Instruments, vol. 13, No. 5, pp. 218–223, 1942.

[4] Kerr, P. F., and Kulp, J. L., Multiple thermal analysis: Science, vol. 105, No. 2729, April 1947.

[5] Kerr, P. F., and Kulp, J. L., Multiple differential thermal analysis: Am. Mineralogist, vol. 33, pp. 387–419, 1948.

[6] Herold, P. G., and Planje, T. J., Modified differential thermal analysis apparatus: Am. Ceramic Soc. Jour., vol. 31, No. 1, January 1948.

[7] Roy, R., Middlesworth, E. T., and Hummel, F. A., Mineralogy and thermal behavior of phosphates. I. Magnesium pyrophosphate: Am. Mineralogist, vol. 33, pp. 458–471, 1948.

[8] Frederickson, A. F., Differential thermal analysis of siderite: Am. Mineralogist, vol. 33, pp. 372–374, 1948.

[9] Gruver, R. M., Precision method of thermal analysis: Am. Ceramic Soc. Jour., vol. 31, pp. 323–328, 1948.

[10] Rowland, R. A., Differential thermal analysis apparatus: Report 101, Shell Oil Co., 1948.

APPARATUS.

Gruver's [9] criticism that little attention is usually given to specific details of construction when reporting new types of apparatus is well founded. It is, therefore, our intention to describe this particular apparatus as completely as possible. Figure 1 shows the complete apparatus and a close-up of the block assembly and recorder.

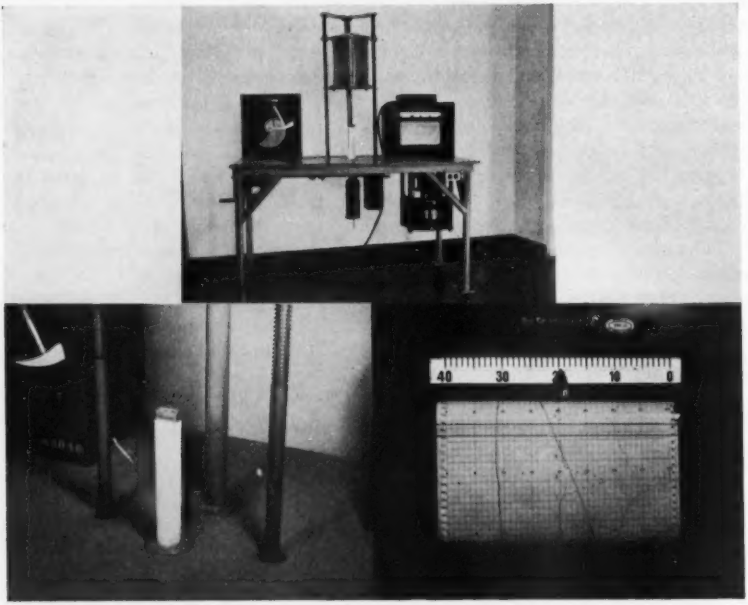

FIG. 1. Photograph of apparatus and close-up of block assembly and recorder.

The essential parts of the apparatus for differential thermal analysis are a sample holder, a heating circuit and a recording circuit. Details and construction of apparatus are given in Appendix.

CLAY MINERALS.

The clay minerals in general are hydrous aluminum silicates and consist of aggregates composed of particles, having excellent cleavage and ranging in size from 3 to 5 microns. Three groups of clay minerals are recognized: kaolin, montmorillonite and illite.

Kaolin Group.—Kaolinite is the commonest member of this group, which also includes dickite, nacrite, halloysite and allophane. They are complex silicates with the general formula $(OH)_8Al_4Si_4O_{10}$. The kaolin group is the

most stable of the clay minerals. There is no tendency for aluminum to be replaced by iron or magnesium because the valency requirements have been satisfied and the structure is balanced. Kaolinite was thought at first to be the most important constituent of all clays. Latest evidence by Grim [11] and others, however, shows the absence of kaolinite in many clays. It is, however, usually the main constituent of residual and sedimentary kaolins.

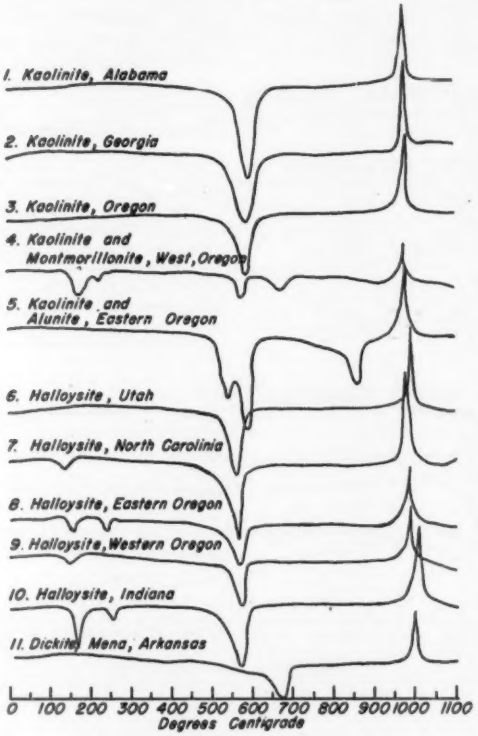
1. Kaolinite, Alabama
2. Kaolinite, Georgia
3. Kaolinite, Oregon
4. Kaolinite and Montmorillonite, West, Oregon
5. Kaolinite and Alunite, Eastern Oregon
6. Halloysite, Utah
7. Halloysite, North Carolinia
8. Halloysite, Eastern Oregon
9. Halloysite, Western Oregon
10. Halloysite, Indiana
11. Dickite, Mena, Arkansas
0 100 200 300 400 500 600 700 800 900 1000 1100
Degrees Centigrade

FIG. 2. Kaolin group minerals.

Montmorillonite Group.—Included in this group is the most common member, montmorillonite, also beidellite, nontronite and saponite. The general formula of the group is $(OH)_4Al_4Si_8O_{20}nH_2O$. Like the kaolin group they are alumino-silicates but the Al : Si ratio is lower. Montmorillonite is considered to have a three layer lattice structure. It is this lattice arrangement that accounts for the loosely held water. It is so loosely held that the water content

[11] Grim, R. E., and Rowland, R. A., Differential thermal analysis of clays and other hydrous materials: Am. Mineralogist, vol. 27, pp. 746–761, 1942.

of the mineral may vary perceptibly with changes in humidity. Unlike stable kaolinite there is a tendency for ions having low valence to replace both aluminum and silicon, thus leaving unbalanced charges that can be neutralized by sodium, calcium or magnesium. This explains the base exchange properties of the group.

Illite Group.—Illite or "hydromica" has been recognized for some time as a mica-like material formed during the alteration of feldspathic minerals to kaolin. It differs optically, structurally and chemically from mica. A more recent concept is that this group is formed as an intermediate alteration product

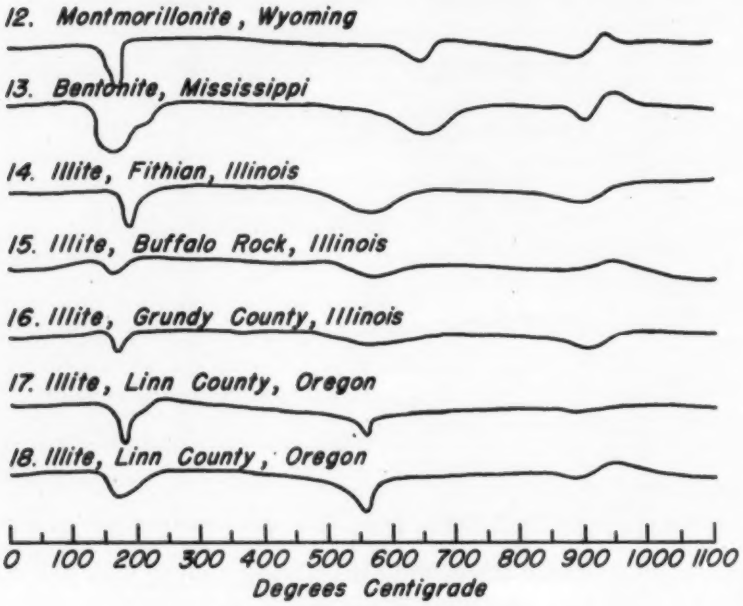
12. Montmorillonite, Wyoming
13. Bentonite, Mississippi
14. Illite, Fithian, Illinois
15. Illite, Buffalo Rock, Illinois
16. Illite, Grundy County, Illinois
17. Illite, Linn County, Oregon
18. Illite, Linn County, Oregon
0 100 200 300 400 500 600 700 800 900 1000 1100
Degrees Centigrade

FIG. 3. Montmorillonite and illite.

developed in clays and shales of sedimentary origin. The general formula is considered to be $(OH)_4K_4(Al_4Fe_4Mg_4Mg_6)(Si_{8-y}Al_y)O_{20}$. It has a three-layer lattice similar to montmorillonite but its replacement behavior varies. At times it undergoes base exchange like the montmorillonites and then again is stable like the kaolin group. According to Grim,[11] illite is the most widely distributed clay mineral in present day marine argillaceous sediments.

Figures 2 and 3 illustrate differential thermal curves of kaolinite, halloysite, dickite, montmorillonite and illite.

The kaolin group of clay minerals is characterized by two distinct peaks on the differential thermal curve. There is a relatively large endothermic peak

between 550° C and 700° C and a sharp exothermic peak at 980° C. The endothermic peak represents the loss of water and destruction of the crystal lattice. The exothermic peak is caused by the crystallization of the amorphous alumina to the gamma modification. The temperature of the endothermic peak is different for the various members of the group and affords a means of distinguishing between them. Halloysite generally contains some absorbed water between the lattice layers which is driven off at about 150° C.

Included in Figure 2 are Thomas Alabama Kaolin (Curve 1), Georgia Kaolinite (Curve 2), Oregon Kaolinite (Curve 3), Mixture of kaolinite and montmorillonite from Western Oregon (Curve 4), Mixture of kaolin and alunite from Eastern Oregon (Curve 5). Various halloysites from Utah (Curve 6), North Carolina (Curve 7), Eastern Oregon (Curve 8), Western Oregon (Curve 9), and Indiana (Curve 10). Dickite from Mena, Arkansas (Curve 11).

Included in Figure 3 are the thermal curves for montmorillonite from Deming, Wyoming (Curve 12) and bentonite from Mississippi (Curve 13). Also the curves of illite from Fithian (Curve 14), Buffalo Rock (Curve 15) and Grundy County (Curve 16) all in Illinois, and two specimens from Linn County, Oregon (Curves 17 and 18).

The Georgia Kaolin, Wyoming Montmorillonite, and Illinois Illite were obtained through the courtesy of Ralph E. Grim of the Illinois State Geological Survey.

HYDROUS OXIDES.

Figure 4 includes the thermal curves of various hydrous aluminum oxides. The most abundant are gibbsite, commonly considered the tri-hydrate $Al_2O_3 \cdot 3H_2O$, and diaspore, the mono-hydrate $Al_2O_3 \cdot H_2O$. A dimorphous form of gibbsite known as bayerite or $Al(OH)_3$ is not found in nature according to Dana. Boehmite, however, dimorphous with diaspore does exist in nature. It is found more extensively in France and other European countries than in this country.

The thermal curve of gibbsite is characterized by a strong endothermic peak at about 350° C. In some cases there is a low temperature peak at about 270° C and another peak at about 550° C. These peaks always occur in the synthetic product of similar composition. The low temperature peak is attributed to a hydrated amorphous material similar to cliachite. At 350° C the material loses 2 molecules of water and is converted to the mono-hydrate which then loses this water at the higher temperature.

Diaspore has a single endothermic peak at about 550° C.

Included in Figure 4 are the curves for Chinese diaspore (Curve 19), Italian bauxite (Curve 20); this curve is identical with that of a French bauxite identified as boehmite. Curve 21 is a high grade bauxite (gibbsite) from Marion County, Oregon.

Curves 22, 23 and 24 represent synthetic tri-hydrates, bayerite and two gibbsites.

Curves 25 and 26 represent two typical Arkansas bauxites. The endothermic peak at about 350° C is due to the gibbsite and the endothermic peak at

about 600° C and the exothermic peak at about 980° C are due to the kaolinite. This is the usual qualitative composition of our domestic bauxites. The higher the gibbsite content the more desirable the material as a source of alumina. Curve 27 represents a laterite from Longview, Washington. According to the curve it is essentially all gibbsite.

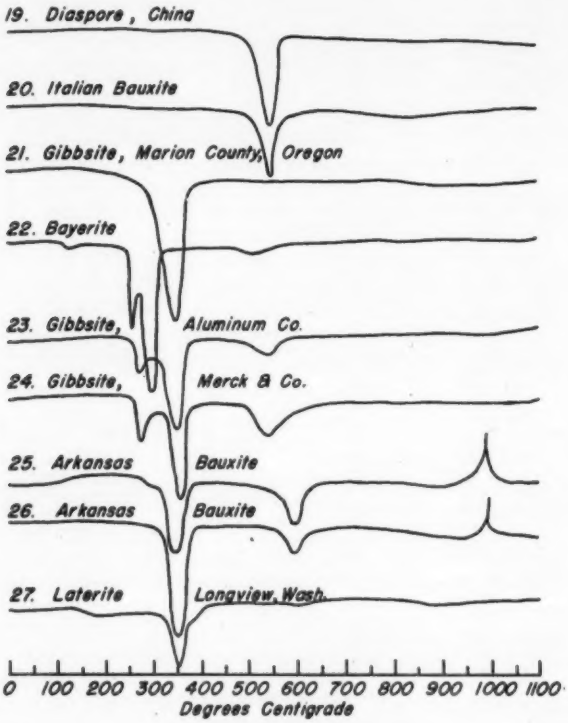
19. Diaspore, China
20. Italian Bauxite
21. Gibbsite, Marion County, Oregon
22. Bayerite
23. Gibbsite, Aluminum Co.
24. Gibbsite, Merck & Co.
25. Arkansas Bauxite
26. Arkansas Bauxite
27. Laterite Longview, Wash.
0 100 200 300 400 500 600 700 800 900 1000 1100
Degrees Centigrade

FIG. 4. Hydrous oxides of aluminum.

Figure 5 includes the thermal curves of magnesium, iron and maganese oxides.

Curve 28 is the characteristic curve for brucite. It dehydrates to periclase at about 480° C.

Curve 29 illustrates the loss of water from goethite at about 390° C. Limonite loses its water at about 320° C as shown in Curve 30.

Also included in Figure 5 are the curves for several manganese oxides. Curves 31 and 32 represent two specimens labeled wad. According to Dana an amorphous manganese oxide containing water is classified as bog manga-

nese. These two curves can, therefore, probably be differentiated on the basis of the low temperature peak in Curve 31.

Psilomelane and pyrolusite can probably be differentiated on the basis of their thermal curves. The former (Curve 33) has a well defined endothermic peak at about 840° C and pyrolusite (Curve 34) has a sharp endothermic followed by a small endothermic at about 670° C and 710° C, respectively.

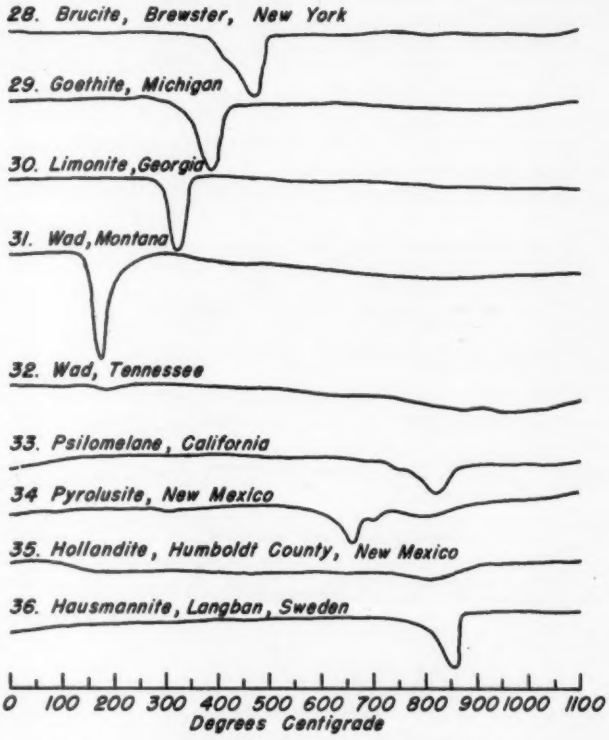
28. Brucite, Brewster, New York
29. Goethite, Michigan
30. Limonite, Georgia
31. Wad, Montana
32. Wad, Tennessee
33. Psilomelane, California
34 Pyrolusite, New Mexico
35. Hollandite, Humboldt County, New Mexico
36. Hausmannite, Langban, Sweden
0 100 200 300 400 500 600 700 800 900 1000 1100
Degrees Centigrade

FIG. 5. Hydrous oxides of magnesium, iron and manganese.

Hollandite (Curve 35) and hausmannite (Curve 36) are not hydrous oxides. Hollandite does not show a sharp peak while hausmannite has a well defined endothermic peak at about 860° C.

CARBONATE MINERALS.

The thermal curves representing the carbonate minerals are characterized by endothermic peaks at various temperatures caused by the evolution of car-

bon dioxide. Manganese and iron carbonates have in addition exothermic peaks caused by the increase in valence of the newly formed oxides.

Figure 6 includes the curves of various carbonate minerals.

Hydrozincite (Curve 37) has a well defined endothermic peak at about 300° C followed by a small double exothermic peak between 340° and 390° C.

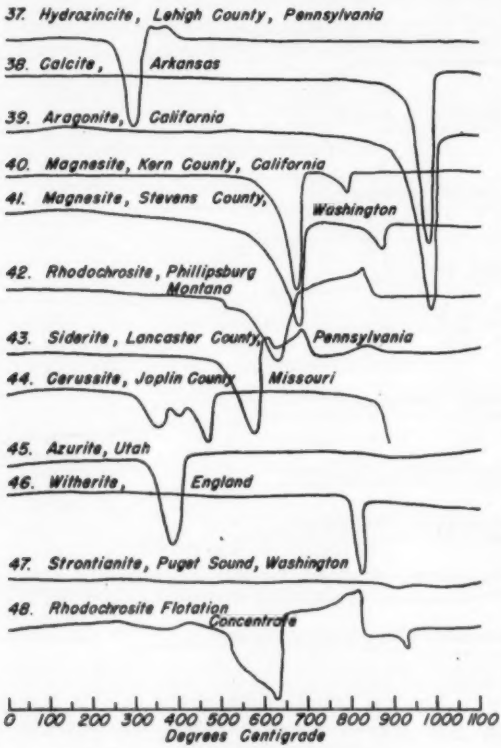
37. Hydrozincite, Lehigh County, Pennsylvania
38. Calcite, Arkansas
39. Aragonite, California
40. Magnesite, Kern County, California
41. Magnesite, Stevens County, Washington
42. Rhodochrosite, Phillipsburg Montana
43. Siderite, Lancaster County, Pennsylvania
44. Cerussite, Joplin County Missouri
45. Azurite, Utah
46. Witherite, England
47. Strontianite, Puget Sound, Washington
48. Rhodochrosite Flotation Concentrate
0 100 200 300 400 500 600 700 800 900 1000 1100
Degrees Centigrade

FIG. 6. Various carbonate minerals.

Curves 38 and 39 for calcite and aragonite, respectively, are identical, having their peaks at about 970° C.

Curves 40 and 41 representing magnesite from different localities have their endothermic peaks at about 670° C. The second endothermic peak at the higher temperature has not been positively identified, but is present in all magnesites examined in this laboratory.

Rhodochrosite (Curve 42) has an endothermic peak at about 630° C followed by a sharp exothermic peak at 840° C.

The thermal curve for siderite (Curve 43) also has an endothermic peak followed by an exothermic. The former is at about 580° C and the latter at 690° C.

Cerrusite (Curve 44) has three endothermic peaks between 300° and 500° C. The lead oxide formed melts in the neighborhood of 880° C. This and several other samples were run to get the thermal curve despite the cost. In these cases the thermocouple, block and porcelain insulators were damaged.

Azurite (Curve 45) has a strong endothermic peak at about 390° C.

Witherite (Curve 46) has an endothermic peak at about 830° C.

Strontianite (Curve 47) does not decompose under 1350° C.

Curve 48 represents a rhodochrosite flotation concentrate. The small endothermic peak at about 930° C may be due to calcite.

Since the curves used in this paper were prepared a detailed study has been made of several rhodochrosite head samples from Phillipsburg, Montana. The study was a practical demonstration of the application of this method of analysis.

Chemical assays of mill products of one of these head samples in particular indicated a large percentage of manganese in the tailing product and rather high lime and magnesia in the concentrate. Grains of pink carbonate, selected under the binocular microscope, yielded a thermal curve that indicated the presence of rhodochrosite, magnesite and mangano-calcite. Selected grains of the white carbonate yielded a curve representative of rhodochrosite and mangocalcite. This intimate mixture suggested the reason for the milling difficulties.

The paper recently published by Kulp, Wright and Holmes [12] on rhodochrosite offers an explanation for the behavior of thermal curves of this substituted mineral. These data seem to be substantiated by some of the curves obtained in the study of the Phillipsburg material. Curves for pure rhodochrosite and the substituted mineral were obtained. In one case there seems to be a mixture of an iron and a magnesium substituted rhodochrosite resulting in a double endothermic peak. The calcite peak was lowered more than 100° C because of the substituted manganese. All of the products were examined spectroscopically to check their cation content.

SILICATE MINERALS.

In Figure 7 appear the thermal curves of various hydrous magnesian silicates.

Curves 49 and 50 represent sepiolite from two different localities. Two low-temperature broad endothermic peaks are obtained. The curves do not agree exactly and yet both specimens were X-rayed and yielded similar diffraction patterns.

Three samples of foliated talc and one of massive talc (steatite) are represented by Curves 51, 52, 53 and 54. They are not spectacular but agree with those found in the literature. The endothermic peak at about 650° C in Curve 52 is probably due to a small amount of impurity.

[12] Kulp, J. L., Wright, H. D., and Holmes, R. J., Thermal study of rhodochrosite: Am. Mineralogist, vol. 34, pp. 195–219, 1949.

The four samples of serpentine, Curves 55, 56, 57 and 58, have similar peaks. The endothermic peak at about 690° C and the exothermic peak at about 790° C seem characteristic.

Curve 59 representing deweylite is very distinctive. A low temperature endothermic peak and one at 600° C followed by an exothermic peak at about 810° C are obtained.

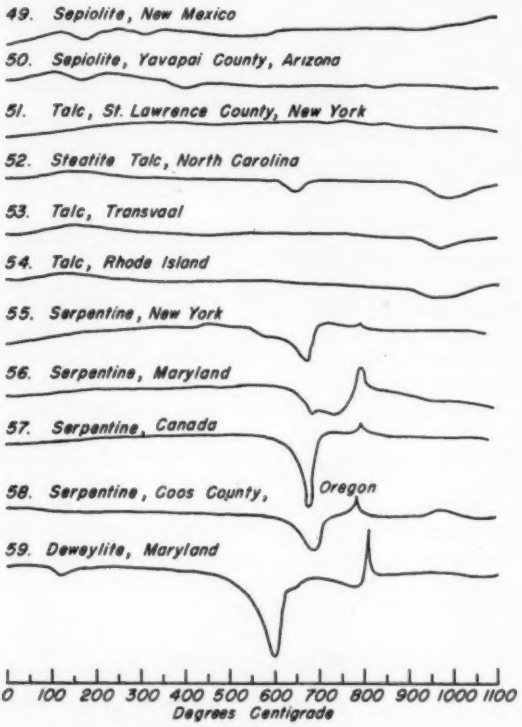
49. Sepiolite, New Mexico
50. Sepiolite, Yavapai County, Arizona
51. Talc, St. Lawrence County, New York
52. Steatite Talc, North Carolina
53. Talc, Transvaal
54. Talc, Rhode Island
55. Serpentine, New York
56. Serpentine, Maryland
57. Serpentine, Canada
58. Serpentine, Coos County, Oregon
59. Deweylite, Maryland
0 100 200 300 400 500 600 700 800 900 1000 1100
Degrees Centigrade

FIG. 7. Various hydrous magnesian silicates.

Figure 8 includes the thermal curves of various hydrous and anhydrous silicate minerals.

Curves 60, 61 and 62 represent glauconite from three different localities. The curves are not in close agreement and yet the X-ray patterns identify all three materials as glauconite.

The curve of chlorite (Curve 63) has endothermic peaks at 660° and 750° C and an exothermic peak at about 870° C.

Two samples of allanite (Curves 64 and 65) are identical. Each has a low temperature endothermic peak and a combination endothermic-exothermic peak between 950° and 1020° C.

Glaucophane (Curve 66) has a single endothermic peak at about 990° C.

Hillebrandite (Curve 67) has a well developed endothermic peak at about 600° C.

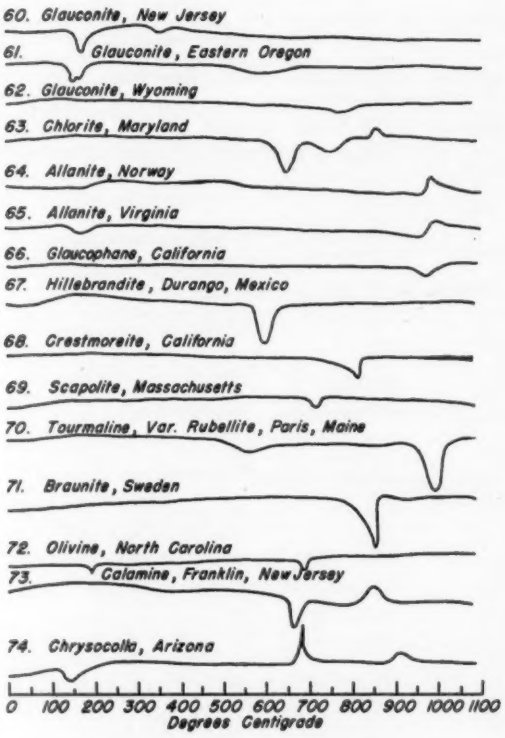
60. Glauconite, New Jersey
61. Glauconite, Eastern Oregon
62. Glauconite, Wyoming
63. Chlorite, Maryland
64. Allanite, Norway
65. Allanite, Virginia
66. Glaucophane, California
67. Hillebrandite, Durango, Mexico
68. Crestmoreite, California
69. Scapolite, Massachusetts
70. Tourmaline, Var. Rubellite, Paris, Maine
71. Braunite, Sweden
72. Olivine, North Carolina
73. Calamine, Franklin, New Jersey
74. Chrysocolla, Arizona
0 100 200 300 400 500 600 700 800 900 1000 1100
Degrees Centigrade

FIG. 8. Various silicate minerals.

The curve for crestmoreite (Curve 68) shows a small endothermic peak at about 820° C.

Curve 69 of scapolite shows a small endothermic peak at about 720° C.

Tourmaline (Curve 70) has a broad, shallow endothermic peak at about 560° C and a large peak at about 1000° C.

Braunite (Curve 71) has a single well defined endothermic peak at about 855° C.

Curve 72 of olivine shows two small, sharp endothermic peaks at about 200° C and 690° C.

Calamine (Curve 73) has an endothermic peak at about 660° C and an exothermic peak at 850° C.

Curve 74 of chrysocolla has a low temperature endothermic peak and two exothermic peaks, a sharp one at about 690° and a rounded one at about 910° C.

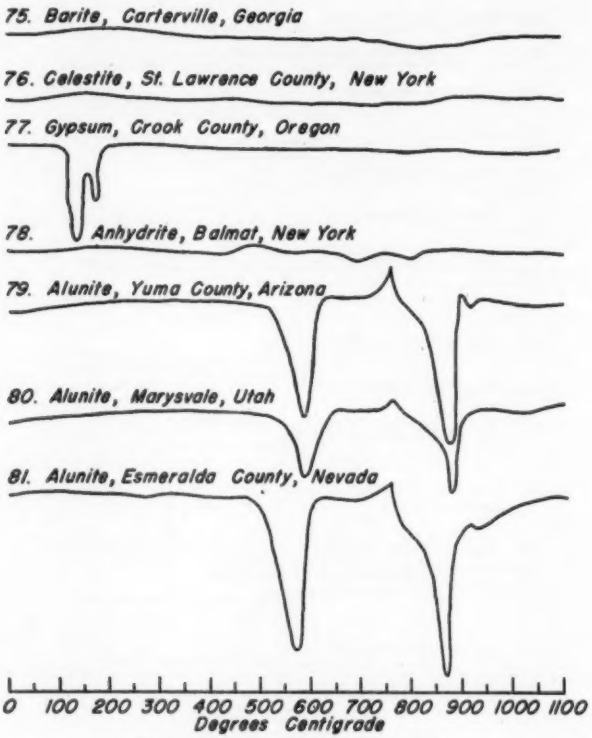
75. Barite, Carterville, Georgia
76. Celestite, St. Lawrence County, New York
77. Gypsum, Crook County, Oregon
78. Anhydrite, Balmat, New York
79. Alunite, Yuma County, Arizona
80. Alunite, Marysvale, Utah
81. Alunite, Esmeralda County, Nevada
0 100 200 300 400 500 600 700 800 900 1000 1100
Degrees Centigrade

FIG. 9. Various sulphate minerals.

SULPHATE MINERALS.

Figure 9 lists various sulphate minerals.

Curves 75 and 76 for barite and celestite do not show any significant peaks over the temperature range.

Gypsum (Curve 77) has a double endothermic peak between 100° and 200° C. The initial peak is thought to represent the loss of 1½ molecules of water and the second peak the loss of the remaining water to form anhydrite.

Curve 78, representing anhydrite, obviously needs further study. The exothermic peak and two endothermic peaks may be due to impurities since they do not occur in the gypsum curve after the dehydration temperature.

Curves 79, 80 and 81 represent three alunite samples from different localities. They are all very similar, having sharp endothermic peaks at about 590° C and 875° C and an exothermic peak at about 760° C.

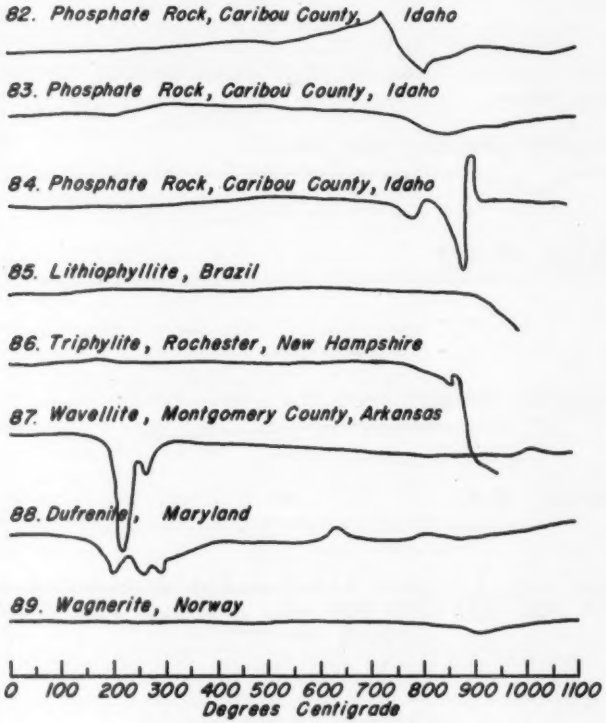
82. Phosphate Rock, Caribou County, Idaho
83. Phosphate Rock, Caribou County, Idaho
84. Phosphate Rock, Caribou County, Idaho
85. Lithiophyllite, Brazil
86. Triphylite, Rochester, New Hampshire
87. Wavellite, Montgomery County, Arkansas
88. Dufrenite, Maryland
89. Wagnerite, Norway
0 100 200 300 400 500 600 700 800 900 1000 1100
Degrees Centigrade

FIG. 10. Phosphate minerals.

PHOSPHATE MINERALS.

In Figure 10 are listed the thermal curves for various phosphate bearing samples.

Curves 82, 83 and 84 represent three western phosphates. The peaks have not been identified but more work will be done on these curves during the course of an investigation of western phosphates.

Curves 85 and 86 represent two phosphate minerals with relatively low melting points.

The curve for wavellite (Curve 87) is rather distinctive. A rather large endothermic peak at about 230° C is followed by a much smaller one at about 260° C. The exothermic peak at about 1000° C may not be significant.

Curve 88 representing dufrenite has three endothermic peaks between 150° and 300° C, and two exothermic peaks at about 640° C and 810° C.

Wagnerite (Curve 89) has a shallow endothermic peak at about 910° C.

VOLCANIC GLASSES.

Four thermal curves (90, 91, 92 and 93) are offered in Figure 11 representing two types of volcanic glass from several localities. No significant peaks were obtained.

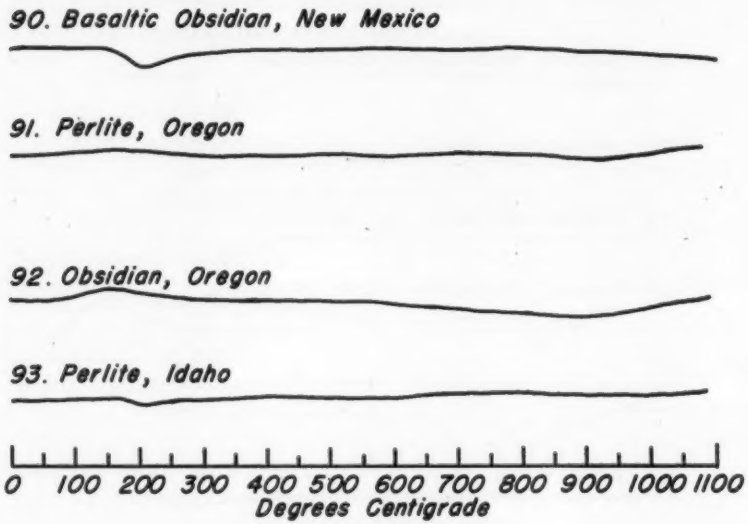
90. Basaltic Obsidian, New Mexico
91. Perlite, Oregon
92. Obsidian, Oregon
93. Perlite, Idaho
0 100 200 300 400 500 600 700 800 900 1000 1100
Degrees Centigrade

FIG. 11. Volcanic glasses.

MISCELLANEOUS MINERALS.

In Figure 12 are found the thermal curves of various minerals determined for this paper and not included elsewhere.

Curve 94 for fluorite shows a small sharp endothermic peak at about 760° C and a broad shallow endothermic peak at about 840° C.

The curve for cryolite (Curve 95) shows the endothermic peak at 570° C representing the change to the isometric modification. This reaction is reversible. The heating of this sample was stopped before the melting point was reached.

Curve 96 for alabandite seems to be characterized by a double endothermic reaction between 450° and 620° C.

The transition point of isometric sphalerite to hexagonal wurtzite is given as 1020° C. This reaction, however, is masked by the strong exothermic reaction representing the rapid oxidation of the mineral. Curve 97 shows the resulting exothermic peak.

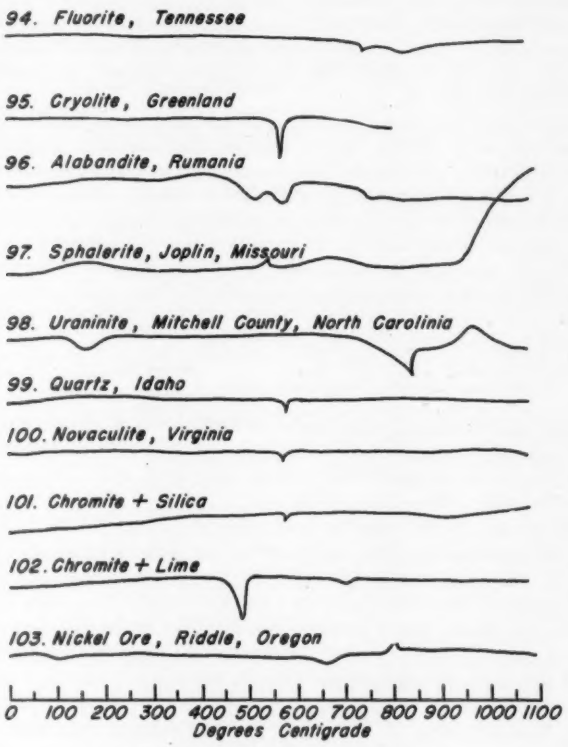
94. Fluorite, Tennessee
95. Cryolite, Greenland
96. Alabandite, Rumania
97. Sphalerite, Joplin, Missouri
98. Uraninite, Mitchell County, North Carolinia
99. Quartz, Idaho
100. Novaculite, Virginia
101. Chromite + Silica
102. Chromite + Lime
103. Nickel Ore, Riddle, Oregon
0 100 200 300 400 500 600 700 800 900 1000 1100
Degrees Centigrade

FIG. 12. Miscellaneous minerals.

Curve 98 represents uraninite from Mitchell County, North Carolina. There is a low temperature endothermic peak at about 175° C and a higher endothermic peak at 850° C. There is also a rather broad exothermic peak at about 970° C. Additional study is contemplated to identify the peaks in this curve and others in this paper that are left unexplained.

Curves 99 and 100 representing quartz and novaculite are identical. The alpha to beta transition is given as 573° C.

Curves 101 and 102 are presented to illustrate one of the applications of this method of analysis to problems other than routine mineral identifications. The problem briefly was to determine whether there was a reaction between chro-

mite and silica (quartz) or between chromite and lime under 1000° C. Curve 101 represents the mixture containing silica. The only break in this curve is the alpha to beta quartz transition. Curve 102 indicates a reaction with the lime at about 710° C. The endothermic peak at about 490° C represents the loss of adsorbed water from the lime.

Curve 103 represents a sample of nickel ore from Riddle, Oregon. There is a low temperature endothermic peak at about 100° C and a higher temperature endothermic peak at about 660° C. This is followed by a rather sharp exothermic peak at 800° C.

The method of differential thermal analysis has proven itself to be a most satisfactory means of identifying the various clay minerals. Many hydrous oxides and silicates, as well as carbonates, can also be readily identified by this method. The method, however, is not limited to simple mineral identifications. This is demonstrated by various accounts reported in the last few years.[7, 13, 14, 15]

A program is being outlined at present, in this laboratory, to examine various metals, especially zirconium and its alloys, in controlled atmospheres. This type of differential thermal apparatus with the electronic recorder is superior to the conventional apparatus usually used in thermal examination of metals and alloys.

APPENDIX: DETAILS AND CONSTRUCTION OF APPARATUS.

Sample Holder.—The sample holder or block is made from a piece of high purity 1½ in. nickel round stock. Chrome-nickel steel is preferred by some investigators. A rectangular block 1½ in. long, 1 in. wide and ⅝ in. high is cut from this stock. Four ¼ in. holes are drilled through the block. A small hole approximately ¼ in. deep is drilled into the center of the block on the underside to accommodate the control thermocouple. Three of the ¼ in. holes are for the samples and the other for the reference material. Two-hole unglazed porcelain insulating tubes ¼ in. O.D. × 18 in. long with a 0.019 in. bore fit snugly into the lower portion of each of the ¼ in. holes of the block. These insulating tubes serve a twofold purpose—they contain the thermocouple wires and also limit the depth of the holes in the block. The entire block can be removed, after a run, usually without disturbing the sample. This is only necessary, however, when the sample sinters and extreme care must be taken to free the thermocouple wires without breaking them. These insulating tubes are cemented (Norton's No. RA562 Alundum Cement) in a 1⅝ in. O.D. × 1¼ in. I.D. × 18 in. alundum tube which acts as the hearth upon which the sample block rests.

Heating Circuit.—The essentials of the heating circuit are a contactor, adjustable transformer, program controller and furnace. Figure 13 shows the schematic wiring diagram of this circuit.

[13] Nagy, R., and Chung Kwai Lui, Thermal and X-ray analyses of some common phosphors: Optical Soc. America Jour., vol. 37, pp. 37–41, 1947.

[14] Rice, A. P., Differential thermal analysis studies in some silicate systems: Electrochem. Soc. Jour., vol. 96, pp. 114–122, 1949.

[15] Kauffman, A. J., Jr., Differential thermal analysis as applied to the lime-soda sinter process: U. S. Bur. Mines Rept. Inv., 4585, 1949.

A. Power for the operation of the apparatus is supplied from a 120 volt AC source. The contactor is a General Electric Magnetic Switch CR7006–D50 and is controlled by hand switch SW6 and switch SW7 in the controller.

B. Power from the contactor is fed through the adjustable transformer T1 to the furnace through P1. This is a General Radio adjustable transformer type 50–A, driven by a Minneapolis-Honeywell Modutrol Motor, type M904E1C1.

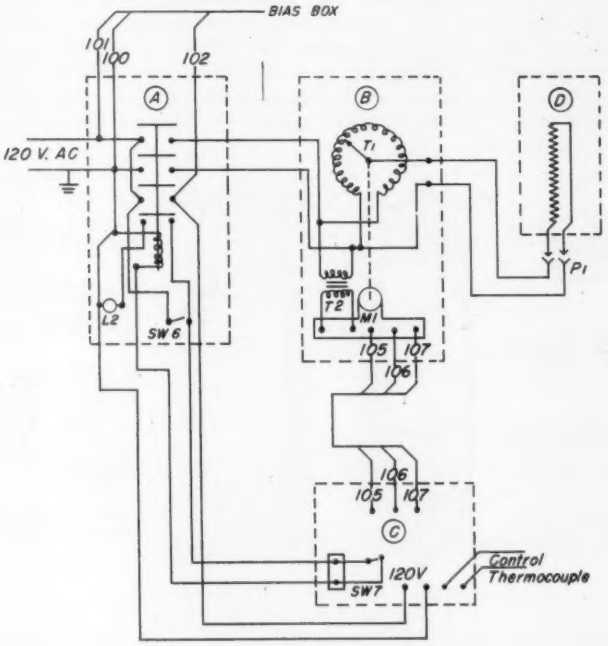

FIG. 13. Heating circuit.

C. It is desirable to control the temperature of the furnace within narrow limits, and also to be able to obtain reproducible heating curves that will not be affected by variations in line voltage or by the temperature of the furnace at the beginning of a run. On occasion it may also be desirable to obtain a cooling curve to check reversible reactions. Comparable temperature control cannot be obtained by using a variac with a direct and non-variable motor drive. There are several types of program controllers on the market that are satisfactory. However, one was not available at the time the apparatus was being constructed so it was decided to convert a Brown circular chart recorder.

The recording chart was removed and in its place a circular cam, cut to give the desired heating rate (10–12° C per minute), was substituted. The chart

drive was replaced by one making a complete revolution in 2 hours. A Chromel-Alumel control thermocouple is used.

An arm riding on the cam positions a small rider on a resistance causing it to move upward as more power is needed to maintain a constant heating rate. Leads from this slider and resistance are connected to the Modutrol motor and it positions itself and the adjustable transformer proportionally to the position of the slider. Any deviations of the heating rate from the desired curve can be noted by observing the position of the temperature indicating pointer with relation to the cam riding arm. An additional potentiometer was added to note this departure and cause the Modutrol motor to correct the difference. This assures an essentially constant and reproducible heating curve independent of factors such as variations in line voltage and initial furnace temperature.

The controller will program cooling curves, if desired, simply by using a cam of opposite cut.

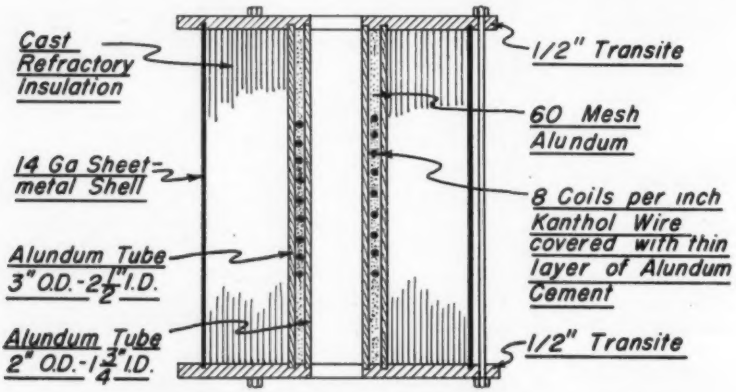
Cast Refractory Insulation
14 Ga Sheet-metal Shell
Alundum Tube 3" O.D.-2 1/2" I.D.
Alundum Tube 2" O.D.-1 3/4" I.D.
1/2" Transite
60 Mesh Alundum
8 Coils per inch Kanthol Wire covered with thin layer of Alundum Cement
1/2" Transite

FIG. 14. Differential thermal furnace.

An additional switch SW7 was added to shut off the power when the desired maximum temperature has been reached.

D. The furnace was constructed at the laboratory. It is an electrical resistance tube type with overall dimensions, 12 in. high and 9¼ in. diameter. The body is a steel shell with transite ends. The middle 6 in. of a 2 in. O.D. × 1¾ in. I.D. × 12 in. alundum tube is wound with approximately 8 coils per inch of kanthal wire (A–1, 0.040 in.). This tube fits into another alundum tube 3 in. O.D. × 2¼ in. I.D. × 12 in. and the space between filled with 60 mesh alundum. This double tube allows the heating element to be replaced with a minimum of effort. The body of the furnace is insulated with cast Insulag cement.

The furnace is mounted vertically and raised and lowered by means of two screws geared to a common crank. It is planned to install a motor drive at some future date. The hearth tube fits loosely into the furnace tube and when

the furnace is lowered the sample block is centrally located. A removable refractory plug seals the upper half of the furnace tube. Figure 14 shows a vertical section of the furnace construction.

The power from the adjustable transformer is fed through the bayonet type plug mounted on the bottom transite end of the furnace. This type of plug is desirable because it eliminates dangling wires and adds a safety factor. The circuit cannot be completed unless the furnace is lowered into position for a run.

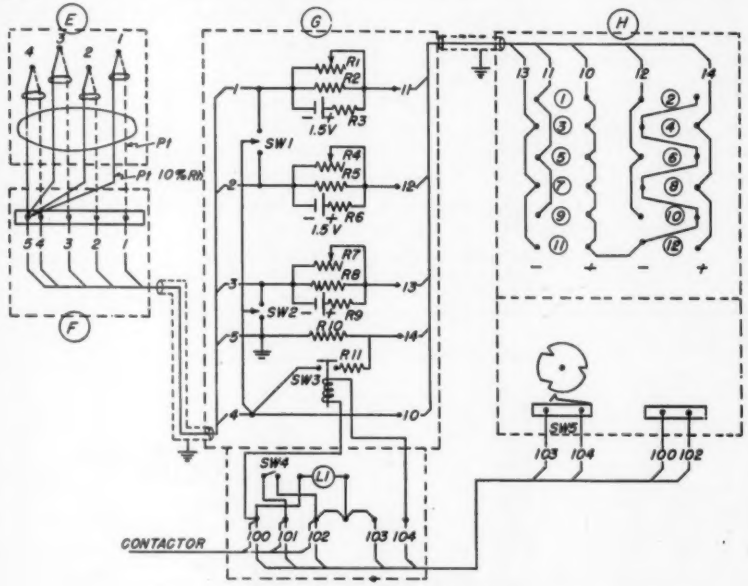

FIG. 15. Recording circuit.

Recording Circuit.—Figure 15 is a schematic drawing of the recording circuit including the recording thermocouples, cold junction, bias box and recorder. Table 1 contains the legend for the various figures.

E. Platinum-platinum 10 percent rhodium thermocouple wire (0.010 in. diameter, thermal element grade) is used. These couples produce an e.m.f. of approximately 10 microvolts per degree centigrade. The maximum average deviation from furnace temperatures due to an endothermic reaction is 8–10° C in this type of analysis. This will produce an e.m.f. of about 80–100 microvolts when using these couples. Other thermocouples have greater sensitivity but the platinum-platinum 10 percent rhodium couples have longer life and greater sustained accuracy when used repeatedly at temperatures as high as 1200° C. They also have a lower limit of departure over this temperature range.

TABLE I

R1—R4—R7	100 ohm wire wound potentiometers
R2—R5—R8	11.5 ohm manganin resistor
R3	150,000 ohm precision resistor
R6	75,000 ohm precision resistor
R9	50,000 ohm precision resistor
R10	1450 ohm precision resistor
R11	50 ohm precision resistor
SW1—SW2	SPDT Toggle switches (spring to center)
SW3	SPST Relay 110 V ac Coil
SW4	SPST Toggle switch
SW5	SPST Micro switch
SW6	SPST Toggle switch
SW7	SPST Micro switch
L1	Pilot light on bias box
L2	Pilot light on furnace contactor
M1	Modutrol Motor driving adjustable transformer
P1	Furnace plug which engages when furnace is in operating position
T1	Adjustable transformer 0–120 V output
T2	Control motor transformer 24 V secondary

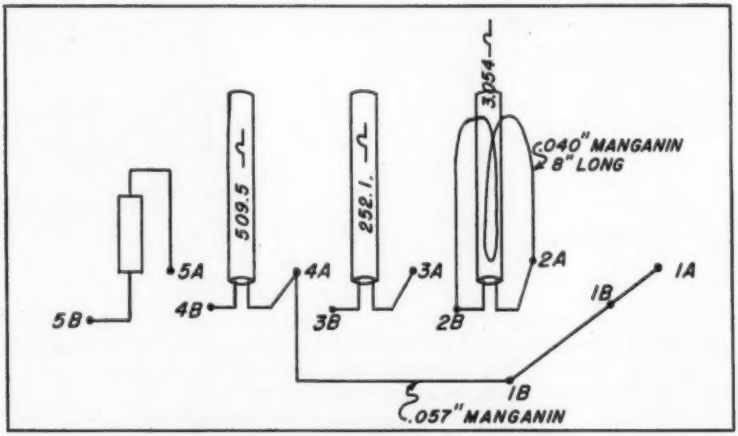

FIG. 16. Potentiometer resistor board.

The couples are arc welded by using either a 6 volt storage battery or other direct current source. This is easily accomplished by placing the ends of the wires, in contact, on a copper plate that serves as one terminal, and lightly touching the ends with a sharpened carbon electrode that is attached to the other terminal. If the wires are aligned properly a light touch with the sharpened electrode will produce a perfect join.

F. The thermocouple wires go from the sample block through the porcelain insulating tubes to a cold junction (thermos bottle) arranged directly below the hearth tube. Connections are made on a terminal strip and copper leads are fed into the bias box through a shielded cable.

G. A fixed small voltage (bias) is applied to each of the three differential traces in order to provide a separation of the base lines on the record. The base lines can be checked by means of switches SW1 and 2. If adjustments are necessary the input can be shorted and the variable resistors R1, R4 or R7 adjusted to zero the trace.

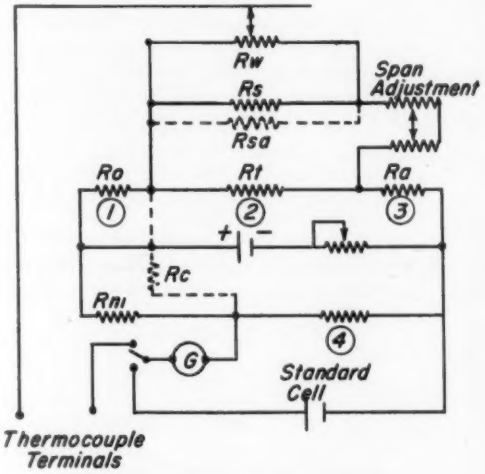

FIG. 17. Potentiometer schematic.

The actual temperature is obtained from the reference couple by introducing a voltage dividing network consisting of R10 and R11 by closing the relay switch SW3. This network applies $\frac{1}{30}$ of the potential from the couple on the recorder. Thus 12 millivolts will give 400 microvolts or full scale deflection. The relay SW3 is actuated by SW5 in the recorder which is closed when points 4, 8 and 12 are printing.

H. The recorder is a revised Brown Electronik Multipoint Recording Potentiometer model Y 153 × 65 V 12–X–84 (IV). This is a twelve point recorder with a range of 10 millivolts. A "synchroprint" recorder was selected because it is designed to balance and record one potential, then automatically switch to the next potential and in like manner repeat the cycle at a time rate as rapid as the balancing action will permit. A medium speed motor is used and the maximum time cycle is about 20 seconds. The instrument is equipped with a resistor panel shown in Figure 16. The range of the instrument can be changed by changing the resistors on this panel. Minor adjustments can be made in the zero setting by moving the block upon which the slide wire is

mounted. A span adjustment resistor is provided to adjust the instrument at near full scale value. In order to make the records comparable to other work of this type, the instrument scale was changed so that the zero is on the right side rather than the left side of the scale.

Figure 17 is a simplified diagram of the potentiometer circuit included to illustrate the major changes made in the instrument.

The full scale range of the instrument was changed from 10 millivolts to 0.4 millivolt or 400 microvolts by placing a shunt resistance (RSA), consisting of approximately 8 in. of 40 mil manganin wire, across resistance RS (3.054 ohm) as shown in Figure 17. The exact value of the resistance was determined by trial and error. It was accomplished by checking the potentiometer against a precision potentiometer with an external potential source. Nearly exact calibration can be attained by fancy manipulation of the last drop of solder. Final adjustment can be made with the span adjustment. This is accomplished after the potentiometer has been properly zeroed and is done near the top of the scale.

During the trial runs a slight drift probably caused by temperature changes was noted. This was eliminated by replacing RO with a jumper of copper wire and shunting RNi with a jumper between 4A and 1B on the resistor panel. This jumper RC has a resistance equivalent of about 1 in. of 57 mil manganin wire. This is sufficient resistance to allow adjustment of the zero point on the slide wire. These changes are all shown as dotted lines in Figure 17.

U. S. Bureau of Mines,
Northwest Electrodevelopment Laboratory,
Albany, Oregon,
Dec. 10, 1949.

LABORATORY POWER SUPPLY FOR VIBRATOR-TYPE PORTABLE GEIGER COUNTERS.

RONALD L. IVES.

INTRODUCTION.

MANY owners of portable Geiger counters find that the instruments are used more frequently in the laboratory than in the field; and that the cost of frequent battery replacements is relatively high. Vibrator-type Geiger counters operating from two flashlight cells (3 volts) can be powered, in the laboratory, from a simple and inexpensive transformer-rectifier-filter device which costs less than eight dollars to build, and less than one cent an hour to operate.

BASIC CIRCUIT.

This power supply consists of a small step-down transformer, which reduces the line voltage to about six volts, and isolates the power line completely from the output. The rectifier is a medium-current bridge-type selenium unit, a standard radio component. The filter is a 1,000 MF dry electrolytic unit, also a standard radio part. The circuit, shown in Figure 1, is a perfectly straight-

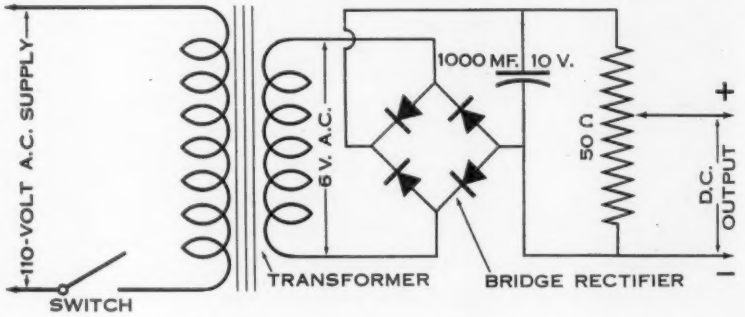

FIG. 1. Circuit of laboratory power supply for three-volt Geiger counter.

forward "battery eliminator" arrangement, such as is commonly used to operate other types of D.C. equipment from the power line. The transformer converts high voltage A.C. to about 6 volts A.C. This is then converted to pulsating D.C. by the bridge rectifier, which is a full-wave device, producing a 120-cycle ripple in the output. This ripple is reduced to a negligible value by the 1,000 MF condenser. Voltage is reduced from the filter output (about 7 volts) to the desired value by a small potentiometer.

CONSTRUCTIONAL FEATURES.

Construction of a power supply of this general type is quite simple, requiring about two hours of shop time. Space requirements are small. All components, chosen with a reasonable margin of safety, can be fitted into a standard 3″ × 4″ × 5″ steel utility case (a standard radio component). Panel control consists of a single off-on switch. To prevent leaving the supply turned on

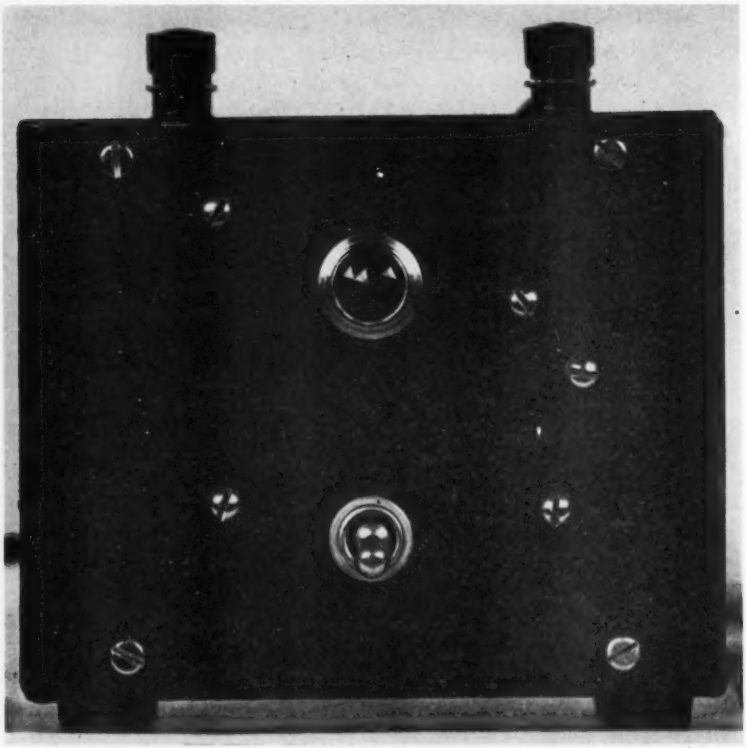

FIG. 2. Panel view of power supply. Switch is at center bottom, pilot light at center top.

when when it is not in use, a pilot light is also mounted on the panel. General appearance of the front panel is shown in Figure 2.

Internal construction depends upon the dimensions of the components, and is not critical. All that is necessary is that the parts be mounted so that they stay mounted; and the connections be made electrically adequate, so that fifteen minutes of trouble shooting is not needed each time the device is to be used.

The potentiometer, used for voltage control, is mounted inside the case, so that it cannot be adjusted without removing the back of the case, intentionally, to forestall the tendency on the part of laboratory assistants (and others) to increase the voltage, in the belief that more volts get more results. Internal construction is shown in Figure 3. All internal components are firmly fastened in place, by use of bolts, angle brackets, and tie strips, so that no part is held in place by its terminals; and all wire connections are firmly soldered at component terminals or to tie strips. Input connection is a standard cord and plug,

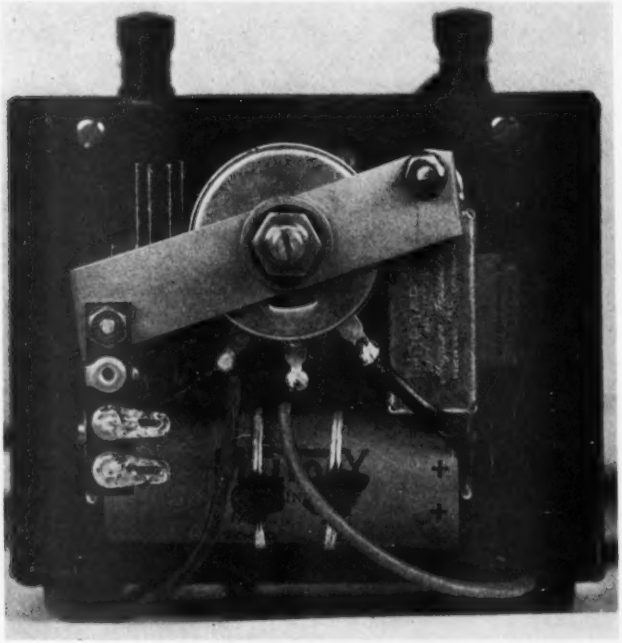

FIG. 3. Interior view of power supply, showing placement of parts, and general mode of construction. Tie terminals at left are for line cord.

connected to the tie terminals at lower left (Fig. 3), and passed through a rubber grommet (to prevent wear and ultimate short circuit) in the back of the case. Output is through a pair of insulated binding posts on top of the case (Fig. 2), polarity being indicated by painting the positive terminal red with cellulose lacquer (red fingernail polish). Rubber feet are mounted on the bottom of the case to prevent skidding, table scratching, and scuffing of the case. Leads from the power supply to the Geiger counter can suit the user's taste. Rubber insulated flexible leads, with spade tips on the supply end, and alligator clips for connection to the counter, have proven satisfactory in practice.

VOLTAGE ADJUSTMENT.

After this supply is electrically complete, but before it is put into service, the output voltage must be set at the requisite value for the counter in use. To do this, remove the back of the case, exposing the potentiometer adjustment. Plug the power supply into the light line, and turn it on. Adjust the potentiometer to about mid-position (half maximum output voltage). Connect the supply to the Geiger counter, with the batteries removed. Connect a high resistance voltmeter across the supply output. Turn adjustment of the potentiometer until voltage is correct (3.2 if the supply is two flashlight cells) when the Geiger counter is operating. Output voltage will now stay constant, so long as the line voltage is also constant, for a period of some months (or years). Disconnect the voltmeter, replace the back of the power supply, and the supply is ready for immediate use at any time.

COMPONENT LIFE.

Case, transformer, potentiometer and switch are substantially immortal, having a service life measurable in decades. Bridge rectifier and electrolytic condenser are commonly rated at 5,000 hours of service life. Many are still in good condition after five or more years of continuous service. Shortest-lived component is the pilot light, which is rated at 500 hours, and costs about six cents.

BATTERY RECHARGING.

It is theoretically possible to recharge flashlight cells, such as are commonly used in portable Geiger counters, by use of a power source such as that described. If a spent cell is connected to such a supply overnight, plus to plus and minus to minus, with the power on, it will have full terminal voltage in the morning, and may perform like a new cell thereafter.

A number of tests indicate that a partly spent cell in good condition can be recharged several times, giving normal output on each discharge. Eventually, however, recharging gives the requisite terminal voltage, but not the expected service life, resulting in the counter rather suddenly "going dead" in the field, usually at maximum distance from a battery replacement. In consequence, although recharging results in a definite dollar saving, this saving is at the expense of dependability, and hence is not recommended.

DEPT. OF GEOGRAPHY,
INDIANA UNIVERSITY,
BLOOMINGTON, IND.,
Jan. 17, 1950.

SCIENTIFIC COMMUNICATIONS

THE COAL DEPOSITS OF COAHUILA, MEXICO.

Both the discovery and the exploitation of Mexican coal are of relatively recent date. It seems that the first news of finding coal in the country can be traced back to the beginning of the last century. Some time passed before due importance was given to such discoveries.

Mexico is a country whose carboniferous reserves are little known, because, with the exception of the Coahuila area there are few data, on the existence of other zones. The known data does not permit the establishment of estimations of total reserves and their full economic value, since they are partially known, and thus indicate little of the volume of their possible underlying masses. Also they show little of the true quality of their coals, because their outcrops are inevitably of bad quality, and probably will not correspond to the deeper zones that did not suffer from the action of external agents. Such has been the experience in the mines now producing.

The deposits of the northern zone are imperfectly known; of the six basins into which it can be divided, only three have been little and poorly investigated in areas close to the outcrops, and never in deep zones that are completely unknown.

The coal deposits of Coahuila are associated with sedimentary Cretaceous rocks, such as limestones lutites and sandstones. Coal, according to what has been found in the different mines, seems to adopt the form of parallel layers with thicknesses of 0.50 m to 2 m.

Fuente Coal Basin.—The coal basin called Fuente, is located close to the Mexico-United States international border, and extends in approximately a southwest direction from Piedras Negras, on the right bank of Río Bravo, to the vicinity of Zaragoza, with an approximate length of 45 km and a width of 18 km, so that the area measures 8000 hectares. This basin, which is the continuation of the basin exploited in the vicinity of Eagles Pass in Texas, has been partly explored by drill holes as well as by other methods, which proved the existence of different carboniferous beds, the most important of which is the one now being worked in different parts of the basin; it shows an average thickness of 1.25 m and is almost horizontal.

Coals of this basin lignites, vary in quality, having the following average analysis:

Ashes	18 percent
Volatile matter	33 percent
Fixed carbon	43 percent
Moisture	6 percent
Calorific power	6100 Cal./kg.

These coals when adequately treated in the laboratory, render a fragile coke.

The reserves at Fuente are not complete, since large regions remain unexplored. If we admit that the whole extent of 8000 hectares of the basin can be utilized, and assuming an average thickness of the coal horizon of 1.25 m, and density of 1.30 for the coal, and using a security coefficient of 0.7, then we have a total reserve of 90 million tons.

Sabinas Coal Basin.—The Sabinas coal basin is the most important in Coahuila and important development work has been done.

The basin takes the form of an irregular oval with a length of some 54 km from SE to NW and with a maximum width of 23–24 km, extending along the rivers Sabinas and Alamos, and 117 km from Piedras Negras. Its surface is estimated to exceed 90,000 hectares.

The exploitation of this basin is concentrated in its northeastern and northern part, and all the work has been done near the outcrops, without reaching the deep part of the basin. The exploration work has been made by means of drill holes, specially around the borders, but the deep sections were left unexplored.

The exploited zone of the Sabinas coal basin can be estimated to cover 20,000 hectares, leaving a virgin area of 70–75,000 hectares. The lack of reconnaissance work does not permit the establishment of exact figures as far as existing reserves is concerned. Nevertheless, taking into account that the exploitable coal bed has an average thickness of 1.50 m, and that the specific weight of the coal is 1.30, one can state that there are almost 1000 million tons within this coal basin.

To judge the quality of these coals, the following average analyses can be quoted:

Origin	Percentage of moisture	Percentage of volatile matter	Percentage of ashes	Percentage of fixed carbon
Mines of San Felipe	2	17	17	64
Mines of Agujita	2	23	20	55
Mines of Cloete	1	19	20	60
Mines of Rosita	2	19	21	58
Mines of Palaú	1	20	18	61
Mines of Palaú (Minerva)	2	15	19	64
Mines of El Menor	1	17	17	65
Mines of La Paloma	4	21	18	57

All these coals produce a siderurgical coke of good quality.

Esperanza Coal Basin.—The Esperanza coal basin is situated to the southwest and very near the Sabinas coal basin, being separated from this by a narrow eroded anticline. It takes the form of a very enlarged oval, of some 40 km in length, and an average of 5 km.

The zone already exploited, more or less efficiently, is now flooded and the shafts have caved. If we discard this and the zone near the outcrops which can be utilized only partially, there remains a zone of virgin coal with an extension of 7400 hectares. The average thickness of the coal can be fixed at 1.20 m, so that the coal reserves can be estimated, within the zone corresponding to the "Cooperativa," at 80 million tons if we use the security coefficient of 0.7%.

There has been no important development nor serious reconnaissance work in the rest of the basin, and therefore only approximately and with a high security coefficient, the reserves can be estimated at 100,000,000 tons.

The coals of this basin can produce good coke, as the following average analysis shows:

	Percentage
Fixed carbon	65
Volatile matter	18
Ash	15
Moisture	2

Saltillito and Lampacitos Coal Basins.—In reality the Saltillito and Lampacitos coal basins are the same thing, since they are only partially separated by a small anticline.

The Saltillito coal basin was partly explored by the Compañía Carbonífera del Norte, S. A." affiliated with the "Fundidora de Fierro y Acero de Monterrey," which made numerous drill holes and thus blocked out some 15,000,000 tons in the examined part. The rest of the basin was estimated to have a reserve of 145,000,000 million tons of good quality coal.

As far as the Lampacitos zone is concerned, which has an approximate extension of 25,000 hectares, and was exploited by the "Compañía de Combustibles Agujita, S. A." only 650,000 tons have been taken out and the work had to be suspended because of difficulties in the production of coke, which swelled inside the furnaces.

The average analysis of this coal is the following:

	Percentage
Fixed carbon	71
Volatile matter	13
Ash	14
Moisture	3

The coal has an average thickness of 1.70 m and the reserves have been estimated to amount to 260 million tons.

San Patricio Coal Basin.—The San Patricio basin is located 35 km to the northwest of Lampazos, and is estimated to cover 180,000 hectares.

Coal Reserves of Coahuila.—Summing up the known data on the coal reserves of the different Coahuila coal basins, we can establish that this State has a total of 1,690,000 tons of coal, as follows:

	Tons
Fuente coal basin	90,000,000
Sabinas coal basin	1,000,000,000
Esperanzas coal basin	180,000,000
Saltillito salt basin	160,000,000
Lampacitos coal basin	260,000,000
San Patricio (without valuation)	
San Blas (without valuation)	
Total:	1,690,000,000

J. González Reyna.

Comite Directivo para la Investigación de los Recursos Minerales en México,
6A. Calle del Ciprés 176,
México, D. F.,
Feb. 5, 1950.

POLARIZATION FIGURES AND ROTATION PROPERTIES—NEW AIDS FOR THE MINERAGRAPHER.

In 1947 and 1948, optical figures obtained by conoscopic observation of minerals in reflected light were discussed by G. J. Neuerburg,[1] and a number of examples were described and illustrated. As no explanation of these figures has been forthcoming, however, their meaning and usefulness in the study of ore minerals have remained in doubt.

Studies in progress at the University of Wisconsin have indicated an explanation of the figures and have demonstrated that they afford a new set of optical criteria for the identification of ore minerals. The optical properties involved are quickly and readily determined with standard mineragraphic equipment in approximately the amount of time required for obtaining and analyzing interference figures given by anisotropic minerals in transmitted light.

With conoscopic observation between crossed nicols, two basic types of figures are given by ore minerals in reflected light. Isotropic minerals give a figure similar to the centered cross obtained from a basal plate of a uniaxial mineral in transmitted light. Basal sections of uniaxial minerals give a similar cross. All other sections of anisotropic minerals give a cross at four positions of the microscope stage 90 degrees apart. At intermediate positions the cross separates into two isogyres resembling those of a centered acute bisectrix interference figure obtained from a transparent biaxial mineral in transmitted light at the 45-degree positions of the optic plane.

The figures have little in common with interference figures other than form. They result essentially from the combined effects of (1) convergence and consequent rotation of the azimuths of polarization of a large proportion of the rays in the incident beam by passage through the objective, (2) further rotation of the azimuths of polarization of the convergent rays upon reflection at the polished surface, independent of the effect of the mineral section, and (3) an additional rotation of the azimuths owing to the action of the mineral section. In cruciform figures, the dark cross is the assemblage of points of no rotation of the plane of vibration of the light coming from the polarizer. In the figures that resemble acute bisectrix figures, the isogyres are assemblages of points at which the algebraic sum of the various rotations is zero. Elliptical polarization enters into the origin of the figures given by some minerals; it is responsible for variations in the figures but does not alter their essential form.

In general, four properties of anisotropic minerals can be determined from the polarization figures. The first is the apparent angle of rotation of the plane of polarization for a given wavelength of light, which is a function of the readily measurable separation of the isogyres. The second, measurable thus far only for minerals of moderate to high dispersion, is the apparent dispersion of the angle of rotation of the plane of polarization for various wavelengths of light. The third is the relative dispersion (red relative to blue) of the rotation of the plane of polarization. This can be measured or can be determined qualita-

[1] Neuerburg, G. J., Optical figures obtained with the reflecting microscope: Am. Mineralogist, vol. 32, pp. 527–543, 1947. Effects of rotation of objectives on the optical properties of opaque minerals in polarized light: Am. Mineralogist, vol. 33, pp. 496–502, 1948.

tively from the disposition of color fringes on the isogyres in white light. The fourth is the positive or negative sense of rotation of the plane of polarization with respect to known crystallographic elements of the mineral under observation. The four properties are characteristic for each mineral species of the anisotropic group.

The use of polarization figures has certain limitations, but it is already clear that it will be a considerable aid in the identification of ore minerals. The phenomena are striking; the tests require no special apparatus. Mineral grains as little as 0.01 millimeter in diameter give excellent figures if a pinhole ocular is substituted for the combination of ocular and Bertrand lens usually used for conoscopic observation. For a given unknown mineral, the properties listed can be determined with satisfactory accuracy if grains of various orientations are present in a polished surface. Special oriented sections are not required.

A fuller discussion of the polarization figures, the properties determinable from them, the optical principles involved, and the procedure and equipment employed will be given in a paper now in preparation.

EUGENE N. CAMERON AND LEWIS H. GREEN.

UNIVERSITY OF WISCONSIN,
MADISON, WISCONSIN,
March 1, 1950.

DISCUSSIONS

PEGMATITES OF MONTANA.[1]

Sir: In his recent report on Montana pegmatites, E. Wm. Heinrich [2] includes a brief discussion of corundum deposits southwest of Bozeman and describes them as pegmatites in which large euhedral corundum crystals were the first to crystallize from the magma. I wish to call attention to the alternative hypothesis that the deposits are not pegmatites at all, but instead are metamorphosed lenses and beds of aluminous sedimentary rock in which large corundum crystals were among the latest minerals to develop. A more complete description of the deposits and a fuller presentation of evidence of their metamorphic origin is presented in two reports [3] now being processed for publication by the U. S. Geological Survey.

The narrow sill-like bodies of corundum-bearing rock occur at one or possibly several thin horizons of wide lateral extent in a series of metamorphosed sedimentary rocks consisting chiefly of interlayered quartzite and hornblende-rich gneiss. Foliation of the gneiss is parallel to the quartzite beds, and the tabular bodies of corundum-bearing rock are also parallel to nearby quartzite beds and essentially concordant with the foliation of the enclosing rocks. Some of the corundum-bearing layers are surprisingly uniform in thickness throughout a length of hundreds of feet. If these are pegmatites, it is remarkable that at not one of more than 150 exposures where they were examined do the layers cut across the foliation and banding of the enclosing gneiss or enclose fragments of the wall rock. Metamorphosed sedimentary beds rather than pegmatites should be expected to show the observed relations and distribution.

Heinrich states that a few granitic pegmatites are closely associated with the syenitic corundum pegmatites, and that locally the corundum- and sillimanite-bearing pegmatites grade into granitic pegmatites. I agree with these observations, but disagree with the implication that the two types of rock are genetically related. Granitic pegmatites are associated with all metamorphic rocks of the region; most of the pegmatites are small, irregular, and discordant, and some appear to finger out into the strongly banded gneiss or migmatite. Where granitic pegmatites intersect the corundum layers an intermediate feldspar-rich rock, generally devoid of both quartz and corundum, is commonly present.

The chemical composition of the corundum-bearing layers is very nearly duplicated in sedimentary rocks by impure potash-rich clays (illite) or sericitic

[1] Published by permission of the Director, U. S. Geological Survey.

[2] Heinrich, E. Wm., Pegmatites of Montana: ECON. GEOL., vol. 44, no. 4, pp. 307–335, June–July, 1949.

[3] Clabaugh, S. E., and Armstrong, F. C., Corundum deposits of Gallatin and Madison Counties, Montana (ms.): U. S. Geol. Survey.
Clabaugh, S. E., Corundum deposits of Montana (ms.): U. S. Geol. Survey.

muds containing iron oxides and minor quantities of other impurities. The alumina content of the corundum rock is actually much less than that of most clays, laterites, and bauxite deposits investigated as potential sources of aluminum. Sediments of approximately the same composition as the corundum-bearing rock are uncommon, but they are surely more plentiful than pegmatites of even remotely similar composition.

The texture of the coarse-grained corundum-bearing rock is aptly described as pegmatitic, but only a small fraction of the rock is coarse-grained. Some of the corundum-bearing rock is fine-grained and almost schistose, but typical material from the deposits is similar to that sketched by Heinrich; it is a medium-grained sillimanite-bearing rock streaked and spotted with aggregates of coarse crystals of corundum and perthite. Heinrich states that the rock is "generally somewhat foliated due to biotite orientation"; I found that the coarse-grained aggregates are essentially devoid of foliation, but that the fine- and medium-grained parts are distinctly to strongly foliated, with muscovite, sillimanite, and biotite all showing preferred orientation. Indeed, the typical rock can be described as a medium-grained feldspar-mica-sillimanite-corundum gneiss in which occur islands and stringers of coarse corundum and perthite.

At the Bear Trap deposit part of the corundum-bearing rock contains as much as 60 to 90 percent sillimanite—rather an amazing mineralogic composition for an unmetamorphosed pegmatite, even a hydrothermally altered one! Other parts of the rock in the same deposit are almost equally rich in muscovite. Heinrich noted the local abundance of sillimanite and muscovite and concluded that these two minerals are "clearly later than the other minerals and have been developed at their expense." I agree that feldspar and corundum have been replaced locally by muscovite, and I found a reciprocal relationship in the abundance of sillimanite and corundum in one series of samples from the Bear Trap deposit, indicating that one of the two minerals may have developed at the expense of the other. But corundum partly converted to sillimanite has not been noted in any of the thin sections, which represent 8 or 10 different localities in the 3 deposits. On the contrary, large, skeletal crystals of corundum commonly appear to have grown across and surrounded pre-existing patches of subradial or contorted sillimanite, and sillimanite is absent from a very narrow zone immediately adjacent to the corundum so that the two minerals are rarely in contact, although often in close proximity.

Except for the presence of corundum instead of quartz, the foliated, medium-grained matrix of the typical corundum-bearing rock resembles other sillimanite schists and gneisses, which are generally ascribed to regional metamorphism of aluminous sedimentary rocks. I suggest that these rocks originated in the same fashion, but that the alumina content of the beds was sufficiently high to result in the development of accessory corundum rather than quartz. The pegmatitic texture of parts of the corundum-bearing layers is interpreted as highly localized recrystallization of the sillimanite gneiss into coarse-textured corundum-perthite rock. The recrystallization occurred during the final stages of regional metamorphism after deforming forces had subsided, for the coarse-grained rock is not characterized by banded structure or other evidences of directive fabric. The large size of the crystals indicates

relatively free movement of material in solution, presumably at relatively high temperature. Also during the final stages of regional metamorphism innumerable pegmatites were introduced into the metamorphic rocks and irregular areas of fine-grained rock were converted to strongly banded gneisses by a combination of recrystallization and addition of alkalies and probably of silica. Light and dark minerals were segregated and the texture of the gneiss was coarsened. Temperatures are assumed to have risen during the process of regional metamorphism, reaching their highest point as a subjacent granite batholith came into existence and rose into the overlying metamorphic rocks, accompanied by swarms of pegmatites, and driving before it heated solutions and hyperfusible components. These conditions of high temperature and mobilized solutions approach contact metamorphic conditions, and they are the environment suggested for the development of the coarse-grained parts of the corundum rocks.

Eskola [4] and others have recognized two related phases of regional metamorphism in many regions. The first is marked by strong deformation and consequent development of preferred orientation of mineral grains in the rocks involved. The second phase, generally affecting only the more deeply buried portions of the deformed rocks, is a stage of essentially static thermal metamorphism, usually accompanied by the emplacement of batholiths, the development of migmatites, and possibly granitization. Metasomatism and transfer of material are conspicuous in this deep-seated or plutonic phase of regional metamorphism. Moyd [5] suggested extreme metamorphic processes of this type to account for the banded nepheline syenites and associated corundum-bearing rocks of Ontario. Metamorphism of the ancient sedimentary rocks associated with the corundum deposits in southwestern Montana was evidently not so extreme as that in other regions where extensive migmatites and igneous-appearing rocks have been developed, but the Montana rocks show ample evidence of the introduction of alkalies, especially soda, and of penetration by solutions or "mineralizers" that facilitated recrystallization and reaction.

The development of the corundum-perthite rock from sillimanite gneiss was probably encouraged by the introduction of soda or other alkalies, as illustrated by the following reaction:

Sillimanite	+	Soda	→	Corundum	+	Albite
$6Al_2SiO_5$	+	Na_2O	→	$5Al_2O_3$	+	$2NaAlSi_3O_8$.

The alkali content of aluminous sedimentary rocks is generally less than that of corundum-bearing crystalline rocks. This relation suggests that in general the conversion of a sedimentary rock to a corundum-bearing rock requires or involves enrichment of the rock in alkalies.

Some of the corundum-bearing rock consists largely of muscovite, and from such a rock corundum and feldspar may form during metamorphism without

[4] Barth, T. F. W., Correns, C. W., and Eskola, P., Die Entstehung der Gesteine, pp. 264–267, Springer, Berlin, 1939.

[5] Moyd, Louis, Petrology of the nepheline and corundum-bearing rocks of southeastern Ontario (Abstract): Amer. Mineralogist, vol. 31, p. 201, 1946.

the addition of alkalies:

$$\begin{array}{lllll} \text{Muscovite} & \rightarrow \text{Microcline} & + \text{Corundum} & + \text{Water} \\ H_2KAl_3Si_3O_{12} & \rightarrow KAlSi_3O_8 & + Al_2O_3 & + H_2O. \end{array}$$

The occurrence of aureoles of microcline surrounding corundum crystals in the muscovite-rich rock is in agreement with the proposed reaction. Heinrich noted that the thickness of the shell of microcline is roughly proportional to the size of the enclosed corundum crystal.

The hypothesis of metamorphic origin of the corundum deposits appears to be more nearly adequate than the mode of origin postulated by Heinrich, for it accounts for the form and distribution of the deposits, their varied texture, and their unusual composition, none of which is typical of pegmatites. But I admit readily that some of the evidence is inconclusive, and that possibly a stronger argument for igneous (or even hydrothermal) origin of the deposits can be presented. It was not Heinrich's purpose to argue the origin of individual deposits, but to give us an over-all picture of Montana pegmatites, and the value of his contribution cannot be questioned. But I wish that he had introduced into his report more of the evidence upon which he based his conclusion that the corundum-bearing rocks near Bozeman, the tabular sillimanite-bearing metamorphosed "pegmatite sills" east of Dillon, the Ennis kyanite deposits, and the Dillon sillimanite deposits are pegmatites rather than metamorphosed sediments or hydrothermal deposits.

STEPHEN E. CLABAUGH.

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AUSTIN, TEXAS,
Dec. 6, 1949.

MINING GEOLOGY AND THE ENGINEERING ASPECTS OF MINERAL EXPLORATION.

Sir: On re-reading J. D. Forrester's article in this JOURNAL (vol. 44, no. 6, pp. 545–550) it occurs to me that there may be a deeper reason for the fact that entire generations of geologists hesitate to call themselves or refuse to be called "engineers." Is it ignorance or false pride or unwillingness to face facts? Let us look at other professions.

We find that not all industrial chemists are and want to be called chemical engineers. There are a number of research chemists in industry and their number is growing. The industrial chemist, especially the chemical engineer in actual practice, is more often an operator, a foreman supervising operations. He works from recipes rather than from first principles.

In petroleum industry there is an exploration and an exploitation geologist. The latter is probably very close to an engineer. He may be called a geological engineer or could be called an engineering geologist, although this latter term usually denotes a geologist working on civil engineering problems. Recently the geophysicists have found it necessary to distinguish an exploration geophysicist from a geophysicist (ss).

An exploration geologist in a foreign country on his own has many engineering and supervisory duties to perform, he supervises test pitting, trenching, sampling, he renders accounts for money spent, he supervises labour, he writes for industrial purposes, but does this constitute engineering? The job of the industrial geologist is more often investigation, fact finding, analysis, research, whether in the laboratory, subsurface or surface—rather than engineering.

Perhaps this controversy of geologist versus engineering is less concerned with values than with differences of fields, subtle ones at that. Perhaps the fundamental cause of nomenclatorial uncertainty is the confusion between technology and science. Geology is rapidly on the way to become a method rather than a field of science. And thus it may be desirable to re-define geology before even attempting to define the mining geologist and the mining engineer. Geology in itself is primarily an applied science in the sense that it uses basic principles of Physics, Biology, History and Chemistry and applies these to earth problems. Thus it is intermediate between *pure science* and *technology*.

Perhaps the term "engineering" requires a re-definition too. Some definitions of engineering are far too comprehensive, too wide and thus almost useless. Engineering certainly requires engines and therefore anything not requiring machines is just daily work common to any human effort, not necessarily calling for the services or the knowledge of an engineer.

Science has a dual purpose and use. There is pure and applied science, academic and industrial science. Science cannot be equated with technology nor with industrial operations.

For the time being a distinction between exploration-mining geologist and exploitation-mining geologist seems all that is desirable. Their fields seem self-explanatory.

H. H. SUTER.

TRINIDAD LEASEHOLDS, LTD.,
POINTE-A-PIERRE,
TRINIDAD, B. W. I.,
Dec. 1, 1949.

REVIEWS

Einführung in die Kristallographie. By HANS SCHNEIDERHÖHN. Pp. xi + 360 + 102; figs. 456 in sep. bdg; tbls. 37, two folded. Karl Alber, Freiburg i. Br., 1949. Price, DM 40.–

This work is concerned with the entire field of crystallography: crystal geometry, crystal structure, crystal chemistry, crystal physics; special attention is given to crystal optics, the polarizing microscope, and anomalous anisotropy. The treatment is scholarly but practical, simple, and sufficiently complete for a thorough first course in crystallography. The reviewer is astonished to find no reference to the widely used modern system of symmetry symbols of Hermann and Mauguin, which can be expanded so easily for the description of the 230 space groups.

The author has provided a useful and unusual arrangement of the index to mineral names, which gives in tabular form not only the name, formula and symmetry class, but also (in separate columns for each of the principal divisions of the book) subject notes and page or figure references, so that one sees at a glance what examples are used for each property of crystals. This is useful in finding subjects as well as in finding references to crystalline substances. The conventional index of subjects occupies seven two-column pages. The illustrations are well conceived and well done; they are in a separately bound booklet inside the back cover of the main book. The reader must keep both sections of the book open before him; but on the other hand, he need not leaf through a great many pages to find an illustration referred to later in the text.

HORACE WINCHELL.

Geologia Applicata all'Ingegneria. By A. DESIO. Pp. 851; figs. 305; numerous tables. Ulrico Hoepli, Milano, 1949. Price, 4800 lira.

The field of geology applied to engineering is large and as yet only partly explored. The author, professor of geology at the University of Milan, has undertaken this task and has attempted particularly to explore the border line between geology and engineering.

The interdependence of engineer and geologist is stressed in the introduction. Although their scientific and technical preparations have a fundamentally different basis, their fields of competence overlap and in order to understand each other and cooperate better they should speak the same language. There is, of course, an intimate connection between the geological study of deposits and the concepts and technical procedures involved in their research and utilization. Here, however, the field of activity of the geologist does not coincide with that of the mining engineer. The latter is principally concerned with the exploitation of mineral deposits and the internal and external organization of the mine. But the search for concentrations of useful minerals, the study of their genesis, the interpretation and evaluation of surficial indications of the underlying deposit, all this is the specific field of the geologist. Economic geology, according to the author, is a denomination used mostly by North Americans to designate that branch of technical geology which

could be called geology of mineral raw materials. Mining geology itself could be part of economic geology, if it were not for the fact that the former concerns itself essentially with the geological conditions and genesis of mineral deposits, while the latter considers the deposits as a source of raw materials for industry.

The six chief fields of practical applications of geology, hydrogeology, applied geomorphology, geology applied to construction, mining geology, economic and agricultural geology, are reviewed briefly in the introduction. However, the book is divided into the following parts: Exploration of the Underground, Applied Hydrogeology, Applied Geomorphology, Geology of Construction, and Mining Geology.

The first part, the exploration of the underground, deals with geologic, geophysical, and boring exploration. It is a compendium of elemental physical and structural geology, petrography and paleontology, with sections on geological and relief maps. Applied hydrogeology is subdivided into surficial waters—lakes, drainage and irrigation, glaciers—and subterranean waters—in general, circulation of water in terrains made permeable by porosity, by fissures, springs, wells, trenches and galleries, and search for water. Applied geomorphology deals with the continental relief and its factors, action of solar heat on rocks, of atmospheric agents on the earth's surface, of gravity, of continental waters, of running waters, of lakes, glaciers and seas. Geology applied to construction deals with rocks as natural materials for construction, foundations, roads, canals, railroads, galleries, dikes and dams, airports and cemeteries. This part is the one that deals more with the engineering aspects.

The last part, mining geology, is quite long and could constitute in itself a book. After a few general concepts on the formation and paragenesis of minerals, definition of mineral deposits, their form, nomenclature of veins, deposits in relation to their genesis, structure and texture of mineral deposits, comes a general classification of mineral deposits which is further detailed. They are divided into endogene. exogene and metamorphic deposits. Each type of deposit is further subdivided and examples given for each. The following sections deal with the weathering of mineral deposits, determination of their geologic age, mineral fuels and geologico-mineral prospecting.

This book represents a considerable amount of work. An up-to-date selected bibliography is at the end of each section, covering world-wide literature. The style is clear, the illustrations excellent and the author is to be congratulated.

M. L. MIGNONE.

Must We Hide? By R. E. LAPP. Pp. 182; figs. 13; photos 31. Addison-Wesley Press, Inc., Cambridge, Mass., 1949. Price, $3.00.

The author is well qualified to write about atomic problems since he worked on the atomic bomb project since its early days and was present at most of the tests.

The book is divided into an Introduction and 14 chapters as follows: Atomic Attack; Atomic Bomb Casualties; Air Burst Atomic Bombs; Bikini: Test Baker; Nuclear Radiation and Man; The Bombing of Germany; The Destruction of Japan; The United States under Attack; The Delivery Problem; Active Defense; Target: U. S. A.; Disaster Planning; Dispersion; Of the Future. As can be seen from the headings the book deals with past, present and future problems, and gives many facts about atomic bombs.

The atomic bomb brought with it a new kind of fear, due mostly to its unknown potentialities. Here we are shown, with figures and photographs, that in fact atomic bombing was actually not much more destructive than explosive and incendiary

bombs. This is proved by the comparison between the incendiary bombing of Tokyo and the atomic bombing of Hiroshima. The main difference in the two bombings, however, is that the atomic bombing brings with it unknown and incalculable radiation effects which make it more dreaded.

According to the author, in the eventuality of a future war, atomic weapons might not be the deciding factor for victory; the enemy would be prepared and there would be retaliation which might destroy our industries and, about as important, the morale of the population. Besides, effectiveness could only be achieved by a great number of atomic bombs, which would be sky-high costly and the bombers would have to be protected by a large number of fighting planes. If we were attacked, it would most probably be against what the author calls the "vulnerable heart" of the United States, a relatively small area in our Northeastern part where most of the vital industries are located. Many American cities built as sky-scrapers would be vulnerable targets because of the compactness of buildings and population. This would bring us, as the author does, to an entirely new conception of how cities should be built in this atomic age; it means building cities on spread-out plans if we want to survive a possible atomic bombing.

The book is well written, interesting for the scientist, although with only sufficient scientific explanations to enable the layman to grasp the main facts about the atomic bomb. The figures are clear and the photographs, most of them supplied by the Armed Forces, well chosen to be effective. The title is quite appropriate and the author's answer is that *we must not hide* from facts. The unknown is always more terrifying and every responsible citizen should read this book. The reward to know now at last more about atomic possibilities and how to be prepared is very gratifying.

M. L. MIGNONE.

Have

Industrial Minerals and Rocks, 2nd Edit. S. H. DOLBEAR, Chairman, Editorial Board, Committee on Industrial Minerals Volume. Pp. 1156; illust. American Institute of Mining and Metallurgical Engineers, New York, 1949. Price, $8.00.

The first edition of this volume won for itself the name of being the outstanding book in the world on the subject of industrial minerals (nonmetallic other than fuels). This second edition, completely revised, coming 12 years later, will assure it being again the premier volume on this subject.

The fifty-one chapters are written by recognized specialists in their respective fields. Most of the authors are the same as in the first edition, although death and other reasons have necessitated a few changes.

This type of text matter is one that requires revision, particularly since World War II brought about many changes in the uses, sources, specifications, prices and marketing of so many of the industrial minerals, and has changed their trade patterns. In this volume all of those features and others have been brought up to date and a great amount of new material added. The industrial minerals are treated alphabetically as formerly, but we note the following additional chapters: "Secondary Fertilizer Minerals," by J. W. Turrentine; "Pyrophyllite," by B. C. Burgess; and "Quartz Crystal," by R. B. McCormick. The number of pages has been increased by 201.

Every user, and they are legion, will appreciate this timely new edition.

Friendly China. By BAILEY WILLIS. Pp. 312; numerous sketches. Stanford University Press, Stanford, Calif., 1949. Price, $5.00.

Anyone who read Bailey Willis' earlier volume "A Yanqui in Patagonia" will find that he will also be interested in "Friendly China" based on his travels there in 1903–04. The book is based on a long walk covering two thousand miles to learn something of the geography and geology of that part of Asia. It deals about the China of that time, of the people and geography and bits of geology. It is written in a delightful style, with colorful anecdotes and again with those charming sketches with which the author was so adept.

The Colloid Chemistry of the Silicate Minerals, Agronomy Vol. 1. BY C. EDMUND MARSHALL. Pp. 195; figs. 85; tbls. 20. Academic Press Inc., New York, 1949. Price, $5.80.

This first volume in the broad field of Agronomy has an appeal to the mineralogist, geologist, colloidal chemist, soil scientist and ceramist, all of whom have contributed to it. The subjects treated are: Historical Outline; Introduction to Silicate Structures; Silicates Based on a Three-Dimensional Framework; The Colloidal Properties of the Zeolites; The Structures of Silicates with Planar Frameworks; The Structural Interpretation of Chemical Analyses of the Clay Minerals; The Sizes and Shapes of Clay Particles; The Optical Properties of Clay Aggregates and Suspensions; Adsorption by the Clays and Its Consequences; Clay Acids and Their Titration Curves; Ionic Exchange Reactions of the Clays; Electrokinetic Properties of the Clays; The Mechanical Properties of Clay Suspensions, Sols and Pastes; The Properties of Clay Aggregates and Films.

The first six chapters are largely mineralogy and crystallography. Chapter 7 contains some fine electron microphotographs, the most complete yet published, of the clay minerals showing their sizes and shapes.

This stimulating book, dealing mostly with clays, brings home to us the manner in which modern research has completely revolutionized our thinking.

BOOKS RECEIVED.

CHARLES H. SMITH.

Earth Waves. L. DON LEET. Pp. 122; figs. 58; tbls. 10. Harvard Monographs in Applied Science No. 2. Harvard University Press, Cambridge, Mass., and John Wiley & Sons, Inc., New York, 1950. Price, $3.00. *A fundamental treatment of earth waves with application in geophysical prospecting, earthquakes, blast vibrations, hurricanes, mapping geologic structures, and engineering problems.*

Lehrbuch der Palaozoologie. OSKAR KUHN. Pp. 326; figs. 244. E. Schweizerbart'sche Verlagsbuch, Stuttgart, 1949. Price (unbound) 30 D.M. ($7.20). *Invertebrate and vertebrate.*

Flow Map Showing Movement of Lake Superior Iron Ores and Eastern and Imported Ores for 1947. Size, 22 x 30 in.; scale, 40 miles to inch; colors. Lake Superior Iron Ore Assoc., Cleveland, Ohio, 1949. Price, $1.50. *Depicts flow from sources to consuming centers in colors.*

U. S. Geological Survey—Washington, D. C., 1949.

Prof. Paper 214-D. Petrography of the Island of Hawaii. GORDON A. MACDONALD. Pp. 46; pls. 4; fig. 1. *A study of representative samples of rock types from every volcano on Hawaii by thin sections, mineral grains, and hand specimens.*

Bull. 948-C. Chromite Deposits of Boulder River Area, Sweetgrass County, Montana. A. L. HOWLAND, E. M. GARRELS, AND W. R. JONES. Pp. 21; pls. 6; figs. 2; tbls. 2. *Chromite layers in lower part of the Stillwater complex. About 390,000 short tons of chromite averaging 5 feet in width and 15% Cr_2O_3 have been proved.*

Bull. 955-B. Structural Control of the Gold Deposits of the Cripple Creek District, Teller County, Colorado. A. H. KOSCHMANN. Pp. 41; maps 2. *Describes the vein zones and their relation to structural features of the walls and floor of a steep-walled basin. Points out favorable areas for prospecting in district.*

Bull. 960-F. Geology and Manganese Deposits of the Lucifer District, Baja California, Mexico. IVAN F. WILSON AND MARIO VEYTIA. Pp. 56; pls. 18; fig. 1. *Ore consists of fine-grained cryptomelane and pyrolusite deposited by hydrothermal solutions in tuff beds. Ore body of the order of 300,000 tons containing 40 to 50% Mn.*

Bull. 963-A. Some Mineral Investigations in Southeastern Alaska. W. S. TWENHOFEL, J. C. REED, AND G. O. GATES. Pp. 44; pls. 2; figs. 19. *Describes gold, copper, lead, barite, tungsten, iron, gypsum, asbestos and witherite deposits examined from 1939 to 1944.*

Bull. 966-C. Geophysical Abstracts 138, July–September 1949. MARY C. RABBITT, V. L. SKITSKY, AND S. T. VESSELOWSKY. Pp. 84. *Nos. 11202 to 11441.*

Water Supply Papers.

1029. Ground Water in the Jordan Valley, Utah. G. H. TAYLOR AND R. M. LEGGETTE. Pp. 356; pls. 14; figs. 26.

1030. Quality of Surface Waters of the United States, 1945. Under the direction of C. G. PAULSEN. Pp. 335.

1069. Public Water Supplies in Central and North-Central Texas. R. W. SUNDSTROM, W. L. BROADHURST, AND B. C. DWYER. Pp. 128; pl. 1.

1071, 1075 and 1076. Water Levels and Artesian Pressure in Observation Wells in the United States in 1946. Under the direction of C. G. PAULSEN. **Pt. 1. Northeastern States.** Pp. 459; figs. 28. **Pt. 5. Northwestern States.** Pp. 192; fig. 1. **Pt. 6. Southwestern States and Territory of Hawaii.** Pp. 316; figs. 16.

U. S. Bureau of Mines—Washington, D. C., 1949–1950.

Rept. Inv. 4429. Missouri Valley Manganese Deposits, South Dakota. Pt. III. Mining and Beneficiation Studies. PAUL ZINNER AND W. A. GROSH. Pp. 56; figs. 37. *Improbable that effective mining and operating methods can be devised to produce significant quantities of manganese from natural or artificially weathered-altered shale alone.*

Rept. Inv. 4586. Magnetic Surveys in the Iron Springs District, Iron County, Utah. KENNETH L. COOK. Pp. 78; tbls. 8; figs. 45. *Describes the results of an extensive survey consisting of 62,000 magnetometer stations, over magnetite and hematite contact replacement bodies in limestone.*

Rept. Inv. 4592. Investigation of Christy Titanium Deposit, Hot Spring County, Ark. DONALD F. REED. Pp. 10; figs. 20. *A deposit of brookite fragments imbedded in red clay. Ore body outlined is 900 feet long, 500 feet wide and more than 141 feet deep, containing 5.8% TiO_2 and 0.52% V_2O_5.*

Rept. Inv. 4621. Titanium and Iron Minerals from Black Sands in Bauxite. W. A. CALHOUN. Pp. 17; tbls. 12; fig. 1. *Gives methods of conservation of titanium and iron minerals in the waste products from Arkansas ores.*

Rept. Inv. 4628. Effects of Core Recovery, Diamond Size, and Quality on Cost of Core Drilling in Gneiss. ALBERT E. LONG. Pp. 11; tbls. 6; figs. 4.

Rept. Inv. 4638. Proposed Process for Treatment of Low-Grade Titaniferous Ores. ROBERT T. MACMILLAN, JOSEPH I. DINNIN, AND JOHN E. CONLEY. Pp. 19; tbls. 8; figs. 3. *Laboratory tests on sintering with carbon and soda ash to produce metallic iron and soluble titanates.*

Rept. Inv. 4647. Bureau of Mines Strategic Minerals Development Program. LOWELL B. MOON. Pp. 62. *A summary of exploration and development work conducted by the Mining Division of the Bureau of Mines from 1939 to 1949.*

Inf. Circ. 7536. History of Premium Price Plan for Copper, Lead, and Zinc, 1942–47. H. E. OLUND AND S. A. GUSTAVSON. Pp. 210.

Colorado Scientific Society Proceedings—Denver, 1949–1950.

Vol. 15, No. 4. Stratigraphy of the Pando Area, Eagle County, Colorado. OGDEN TWETO. Pp. 88; figs. 4. *A sedimentary section mainly composed of rocks of Pennsylvanian and Permian (?) ages.*

Vol. 15, No. 5. The Gunnison Forks Sulfur Deposit, Delta County, Colorado. MCCLELLAND G. DINGS. Pp. 20; figs. 3. *Native sulfur bodies of small size, irregular shape and low sulfur content, believed to have been derived from hydrogen sulfide in gas seeps.*

Vol. 15, No. 6. Geology and Fluorspar Deposits of the St. Peters Dome District, Colorado. THOMAS A. STEVEN. Pp. 26; figs. 8. *Fluorite-quartz veins in fractures in Pikes Peak granite.*

Colorado School of Mines Quarterly—Golden, 1950.

Vol. 45, No. 1-A. Economics of the Mineral Industry. Edited by HARRY M. CRAIN. Pp. 47. *3 papers; mineral-resource appraisal by the U. S. Geological Survey, by S. G. Lasky; oil and human welfare, by M. W. Ball; gold, our most strategic mineral, by D. H. McLaughlin.*

Vol. 45, No. 2-A. Petroleum Refining. Edited by HARRY M. CRAIN. Pp. 162; numerous illustrations. *A group of papers delivered at the Conference on Petroleum Refining held at the Colorado School of Mines in 1949.*

Illinois Geological Survey—Urbana, 1949–1950.

Rept. Inv. 145. Niagaran Reefs in Illinois and their Relation to Oil Accumulation. H. A. LOWENSTAM. Pp. 36; figs. 9; pl. 1. *A systematic examination of subsurface Silurian strata of Illinois to determine the occurrence and spacing of reefs.*

Circ. 159. Summary of Research Results on the Geologic Aspects of Radio Wave Transmission. M. WILLIAM PULLEN, JR. Pp. 7; figs. 3.

Geology and Ground-Water Resources of Norton County and Northwestern Phillips County, Kansas. JOHN C. FRYE AND A. R. LEONARD. Pp. 144; pls. 10; figs. 11; tbls. 8. Kansas Geol. Survey Bull. 81, Lawrence, 1949.

Missouri Geological Survey—Rolla, 1949.

Inf. Circ. 3. Coal Production, Distribution and Consumption in Missouri. WALTER V. SEARIGHT. Pp. 52; figs. 12; tbls. 2.

Inf. Circ. 5. Notes on Uranium. GARRETT A. MUILENBURG. Pp. 18. *A general account of uranium, with information on occurrences in Missouri.*

Researches on Ohio Crude Oils. Pt. I. Classification and Evaluation of Ohio Crude Oils. EDWIN E. SMITH AND L. K. HERNDON. Pp. 41; tbls. 6; figs. 11. **Pt. II. An Investigation of the Gasoline Fractions Obtained from a Corning Grade Crude Oil.** CHARLES W. CONKLIN AND THOMAS H. WILSON. Pp. 16; tbls. 10; figs. 13. Ohio State Univ. Studies Engineering Series Vol. 18, No. 5, Columbus, 1949.

The Geology and Ground-Water Resources of Woonsocket, Rhode Island. ALONZO W. QUINN AND WILLIAM B. ALLEN. Pp. 40; pls. 2; figs. 5; tbls. 3. Rhode Island Port and Industrial Development Commission Geol. Bull. 5, Providence, 1950.

Bibliography on Offshore Petroleum Developments. EMORY N. KEMLER. Pp. 16. Southwest Research Inst. Div. of Oceanography and Meteorology Pub. 1, Houston-San Antonio, Texas, 1950.

Report of the Committee on the Measurement of Geologic Time, 1948–1949. JOHN PUTNAM MARBLE, Chairman. Pp. 139. National Research Council, Washington 25, D. C., 1949. *Report of Committee, six supplementary reports, and an annotated bibliography of articles related to the measurement of geologic time.*

Canada Department of Mines—Ottawa, 1949–1950.

No. 827. The Canadian Mineral Industry in 1947. By Staff of Bureau of Mines. Pp. 134.

Bull. 14. Geology of Part of the Selkirk Mountains in the Vicinity of the Main Line of the Canadian Pacific Railway, British Columbia. V. J. OKULITCH. Pp. 21; pls. 4; figs. 4. *A series of unfossiliferous strata below the Olenellus zone.*

Mem. 252. Fort St. James Map-Area, Cassiar and Coast Districts, British Columbia. J. E. ARMSTRONG. Pp. 210; figs. 17; pls. 5; map 1. *Geology and mineral deposits of an 11,000 square mile area in east-central British Columbia. Sedimentary, volcanic, and intrusive rocks ranging from Late Proterozoic to Oligocene. Mercury, gold, copper, silver-lead-zinc, chromium, and nonmetallic mineral deposits described.*

Publications of the Dominion Observatory, Vol. 14, Bibliography of Seismology, No. 5, January to June 1949. W. G. MILNE. Pp. 36. *Items 7004 to 7131.*

Australia Bureau of Mineral Resources—Melbourne, 1949.

The Australian Mineral Industry, Vol. 2, No. 2. Pp. 28; numerous tables.

The Australian Mineral Industry 1948 Review. Pp. 169; numerous tables. *Separate statistical accounts of products of mineral industry.*

Rept. 2. Observations on Stratigraphy and Palaeontology of Devonian Western Portion of Kimberley Division, Western Australia. CURT TEICHERT. Pp. 61; tbls. 2; pls. 6; fig. 1.

The Geology of the Aurora District, Cuyuni River, British Guiana. Pp. 34; figs. 3; map 1. British Guiana Geol. Survey Bull. 21, Georgetown, 1949. *Explanation of sheet No. D. 4 (Aurora). Gold associated with granitic intrusives intruding metamorphic and volcanic rocks. Also placer gold and diamonds.*

Pleistocene Eustasy and Glacial Chronology in Java and Sumatra. G. L. SMIT SIBINGA. Pp. 31; figs. 5; tbl. 1. Amsterdam Univ. Geol. Inst., Holland, 1949. *An attempt to identify Pleistocene eustatic changes of sea level and to correlate them with the corresponding glacial and inter-glacial stages.*

Estudos, Notas e Trabalhos, Vol. 4, Fasc. 3–4. Pp. 72. Portugal Dept. Mines, Porto, 1948. *4 papers on manganese and iron deposits.*

Geologischen Landesanstalt—Berlin, 1948–1949.

No. 78. Beiträge zu Einer Deutung der Metallogenese in Thüringen. ALFRED POLLAK. Pp. 16. *Contributions to an interpretation of the metallogenesis in Thüringen.*

No. 79. Entstehung der Alluvialen Eisenerzlagerstätten Mecklenburgs. KURD VON BÜLOW. Pp. 17; figs. 6. *Origin of the Mecklenburg alluvial iron deposits.*

No. 210. Der Tiefere Untergrund des Westlichen Peribaltikums. RUDOLF VON ZWERGER. Pp. 74; figs. 11; maps 3. *Discusses the relationship between tectonics and gravity and magnetic anomalies around the western Baltic.*

No. 213. Die Gesteine des Unterkarbon von Dobrilugk und des "Algonkium" von Rotstein bei Liebenwerda. ARNO SCHÜLLER. Pp. 12; figs. 3; pls. 33. *The Lower Carboniferous rocks near Dobrilugk, south of Berlin, and so-called Proterozoic siliceous rocks.* **Die Porphyre von Schwerz.** ARNO SCHÜLLER. Pp. 4; pls. 2. *The Schwerz porphyry.*

SOCIETY OF ECONOMIC GEOLOGISTS

GENERAL RESEARCH COMMITTEE, ANNUAL REPORT.

This report represents recommendations from the General Committee, made up of the chairman and associate chairman of each of the six special Committees (also designated Subcommittees) on Research. While entitled an annual report, it actually represents the work carried on since the last meeting of the Council of the Society, held last February at San Francisco at the joint meetings of the Society of Economic Geologists and the American Institute of Mining and Metallurgical Engineers. Strictly speaking, therefore, it is a report of progress for the last nine months.

The *Committee on Coal* has held two meetings during 1949, on March 21st at Pittsburgh and September 27th at Columbus.

Pursuant to recommendations advanced at the Pittsburgh meeting the Chairman presented a paper at the mid-year meeting of the Coal Division of the American Institute of Mining and Metallurgical Engineers explaining the activities of the Coal Research Committee of the Society of Economic Geologists. At a business meeting of the Coal Division, AIME, preliminary steps were taken toward setting up some sort of coal geology group in the Coal Division, AIME. It seems not improbable that joint sessions on coal geology combining these two coal research groups may result. In this connection the plan was advanced that at the next annual review of coal geology research (at the Annual Meeting of the AIME in St. Louis in February, 1951) the general subject would be the geology of mid-western coals. Following recommendations made at the September meeting a memorandum has been prepared recommending that the Council establish a permanent committee on Coal Geology to assume the activities of the Coal Research Committee and to appropriately extend these activities. Signed approval of this plan has been obtained from about 26 of the individuals concerned. The project on fundamental geological research on coal has been prepared in the form of a proposal for presentation to the Council, but it has not yet been circulated among the members of the committee for approval and it remains a question whether this is the most suitable approach to the problem of activation.

The Committee on Ore Deposits.—After the joint meeting of the chairmen of the General Committee on Research with the Council of the Society of Economic Geologists in San Francisco in February 1949, the Chairman and Associate Chairman of this Subcommittee followed the suggestions made at that time to circularize members of our Subcommittee in an effort to learn what was regarded as the most important research problem in the general field of mining geology. The responses showed no unanimity but did indicate that it was difficult to make a decision until the individuals understood the character of the support that would be accorded by the Society of Economic Geologists. It thus became clear that the important and the expedient were not necessarily the same, and that the responses would differ greatly depending on the size of the funds, personnel available length of time involved, and the place where the work was to be done. There was evident a definite feeling that the fundamental problems to be attacked should include the chemical nature of the ore-bringing solutions and the structural factors involved in the preparation of ground locally and regionally. It is believed that the small number of individuals who have given their opinion on this very important subject makes unsatisfactory other than a preliminary report at this time. As a symposium on research in ore deposits was to be held at the El Paso meetings of the Geological

Society of America, it was hoped to get a sufficient cross-section of geological opinion at that time to enable our Subcommittee to draw up definite recommendations that will carry out the spirit of the suggestions made at the San Francisco meeting.

The Committee on Industrial Minerals.—In general, the feeling of this committee has been to prefer getting one project well started, rather than to attempt any stimulation of several projects to begin with. The Committee made a rather searching analysis of the list of topics suggested many months ago as particularly timely ones for fundamental research. Owing to current activities of university staffs, Government agencies of various types, and other organizations, it would appear that many of the items on the list are being taken care of. Others are susceptible to classification by the Federal Government, and hence would not be as satisfactory as those about which information could be freely disseminated. Of the 10 items on the original list, only the one entitled "Zoning in nonmetallic deposits" appears to offer great promise. "Zoning" has been interpreted in its broadest possible sense, and after some deliberation and much discussion it was decided that a broad study of the geology and geochemistry of boron mineralization in the Southwest would constitute an attractive subject. More specifically, we should like to have partial or complete answers to such problems and relations as (a) the stratigraphic relations of boron accumulations, (b) the geographic relations of the deposits, (c) their structural relations, (d) the respective origins of southwestern boron deposits, (e) the ultimate source or sources of the boron, and (f) an explanation and exposition—as full as possible—of the so-called "boron cycle." Thus, the first project recommended is the investigation of the concentration of boron in minable quantity from both the theoretical and practical viewpoints. Some conversations have been held between Committee Chairman Dr. Gillson, Dr. Behre, and the Secretary of The Geological Society of America as to the feasibility of financing the study of this subject through a grant from the Penrose Fund.

The Committee on Petroleum acts solely as a liaison committee with the American Association of Petroleum Geologists' Committee on Research. Our Committee, therefore, reports for record the following: (1) The most ambitious project now receiving attention from the A.A.P.G. is a proposed study of recent and near-recent sediments of the northern Gulf of Mexico with possible extensions into the lime-forming area adjacent to Florida. This study, as formulated after some years of work by a very large committee of the A.A.P.G., would be a comprehensive study of the sedimentology of the area involved, including such aspects of diagenesis of the sediments and the changes in their associated fluids as may be demonstrated by the recent and near-recent sediments. This project is under consideration by the American Petroleum Institute. If that organization decides to finance it, this project will probably be the most ambitious research effort on sediments ever undertaken. (2) A project now in progress, and which is being financed by the American Petroleum Institute, is a study of clay minerals. This work originated in part as the result of a special proposal by Professor Kerr of Columbia and in part from a project formulated and proposed by the A.A.P.G. (3) A project on "Experimental Tectonics" is in progress at College Station, Texas; the Agricultural and Mechanical College of Texas is engaged in the work. (4) A subcommittee of the A.A.P.G. Research Committee is preparing a glossary of terms used in describing conditions in oil and gas reservoirs. (5) The Research Committee of the A.A.P.G. outlined a substantial number of projects on which organized work has not been undertaken. Summary discussions of these projects are in the hands not only of the members of the A.A.P.G. but of many individuals in colleges and universities. The extent to which work bearing on some aspects of some of these problems has been initiated is not known at the present time, but it is believed that a substantial amount of pertinent work is in progress.

The Committee on Engineering Geology.—Research activity in the field of engineering geology was appraised in detail in 1948 (Econ. Geol., Vol. 43, No. 4, June–July 1948, pp. 313–323). It was then determined that research in engineering

geology was advancing on many fronts. Subsequently, the progress of this research has been under continuous informal scrutiny through the Division of Engineering Geology of the Geological Society of America and through the major participating organizations, particularly the U. S. Corps of Engineers, the U. S. Geological Survey, the U. S. Bureau of Reclamation, and the Tennessee Valley Authority. A reappraisal on a formal basis is contemplated for the near future. The 1948 report indicated that research data were then accumulating rapidly through the efforts of a large number of organizations and individuals, and it was then concluded that it was unnecessary for any single group or committee to undertake or underwrite research in engineering geology. This situation still prevails. Admittedly, individual research problems or segments of research activity would advance more rapidly if given greater emphasis or if approached more formally than is now the case through the influence of some guiding body. But at the present time an intensification of research in selected segments of the field would result in a constriction in other segments; and the evolution of engineering geology into a formal and independent specialization of geological science is not sufficiently advanced to permit rational discrimination between those phases of research that could be most advantageously intensified and those that could be sacrificed with least disadvantage. It appears that the principal need now, as in 1948, if research in engineering geology is to be most productive and useful, is the establishment of a mechanism for periodic inventories to record activity and progress and to acquaint participating individuals and institutions with research underway and the results accruing.

The Committee on Ground Water.—During the last six months the work of this Committee included the successful assignment of the last remaining research topic to competent authors, the preparation of a brief introductory report by the chairman, and completion of a report on the "Geochemistry of ground water," by John D. Hem. The two papers previously mentioned are in the hands of the editor and soon are to be published in ECONOMIC GEOLOGY.[1] Papers on the eight remaining research topics will be submitted for publication as they are completed.

General Findings.—In addition to these reports of progress, the General Committee on Research refers the following question to the Council for action in accordance with the wishes of the Council. There has been much discussion as to whether the General Committee is justified in requesting its continuance. The consensus of opinion is that while all of us believe that close contact should be maintained between the Society of Economic Geologists and its sister societies fostering research programs in fields of overlap, it is questionable whether the effort necessary to maintain a committee solely for this purpose is merited. The Ground Water Committee, Petroleum Committee, and the Engineering Geology Committee are already well represented in other societies, namely, the American Geophysical Union, the American Association of Petroleum Geologists, and the Engineering Section of the Geological Society of America; the Chairmen and Co-Chairmen of the Committees in large part occupy prominent roles in planning research in the sister societies just mentioned.

With the other three Committees, the situation is somewhat different. The nearest equivalents to sister organizations are the respective Divisions and Committees of the A.I.M.M.E., though it is to be noted that the National Research Council of Canada and the Canadian Institute of Mining and Metallurgy have both recently established separate organizations, intended to foster basic geologic research on mineral deposits and patterned somewhat along the lines of our Committees. The A.I.M.M.E. Committees and Divisions have not as yet set up plans for systematically advancing basic research on the geology of coal, ore deposits, or industrial minerals. Therefore, these are fields, the basic aspects of which are generally neglected, in which continued planning and stimulation seem to be merited; ours seems to be the Society most immediately concerned with such studies and best adapted for furthering them, because it focuses its attention on geology

[1] These two papers appeared in Vol. 45, no. 1, pp. 70–81, January–February 1950 (Editor).

without suffering from "dilution" by questions of extraction technology, purely economic and social considerations (such as markets, labor and tariffs), and the like.

Recommendations.—1. That the Council discharge the entire General Research Committee with its Subcommittees, and reorganize the structure, as below.

2. That the Council appoint the following: A new standing Committee on *Research on the Geology of Coal,* working, not under a General Research Committee as at present, but under its own governance and reporting directly to the Council; a new standing Committee on *Research on the Geology of Ore Deposits,* working, like the Coal committee, autonomously and reporting directly to the Council; and a new standing Committee on *Research on the Geology of Industrial Minerals,* autonomous, like the two preceding Committees. It is altogether possible that these three new committees will require a structure different from that of the past subcommittees, and any such reorganization should be recommended to the Council in view of the relationships anticipated.

3. That the Council consider the establishment of a Committee on Research Liaison to keep the Society informed as to the activities relative to basic research in petroleum, ground water, and engineering geology as carried on by sister societies. The General Committee on Research is not fully agreed as to the wisdom of establishing such a Committee and takes this method of placing the matter into the hands of the Council.

Conclusion.—Finally, the General Committee on Research emphasizes again its view that the *planning* and *furthering* of basic research in applied geology is of paramount importance. If the somewhat complicated structure recommended above seems cumbersome and officious, it yet appears to be fully justified: it represents what in our opinion should be one of the two major services of the Society of Economic Geologists—a forum for discussing and publishing advances in the field of applied geology and a force for initiating and advancing research toward constructive ends.

With this report, the General Committee requests that it be discharged.

Respectfully submitted,

GILBERT H. CADY, Coal
DONALD M. DAVIDSON, Ore Deposits
JOSEPH L. GILLSON, Industrial Minerals
K. C. HEALD, Petroleum
RICHARD H. JAHNS, Industrial Minerals
S. W. LOHMAN, Ground Water
T. S. LOVERING, Ore Deposits
SIDNEY PAIGE, Engineering Geology
ROGER RHOADES, Engineering Geology
CHAS. H. BEHRE, JR., *Chairman.*

Nov. 1, 1949.

SCIENTIFIC NOTES AND NEWS

N. E. ODELL, recently a Visiting Professor in the Department of Geology, University of British Columbia, and who subsequently did geological work for the expedition of the Arctic Institute of North America in Yukon and Alaska, has gone to New Zealand to take up the Chair of Geology at the University of Otago.

JOHN G. BARAGWANATH, formerly with Freeport Sulphur Co., has become vice-president of the Shelter Rock Development Corporation in charge of its mining and petroleum activities.

HOWLAND BANCROFT has returned to his New York headquarters after having spent seven months in South Africa investigating developments in the gold fields of the Orange Free State.

CHARLES WILL WRIGHT returned in mid-December from a ten weeks' trip to Greece, Italy, France, and Spain.

F. EARL INGERSON, Chief of the Geochemistry and Petrology Branch of the U. S. Geological Survey, has joined the editorial board of Geochemica Acta, a new international journal devoted to the chemistry of the Earth and the Cosmos, and will serve as American editor of the new journal, to be published in London, England, by Butterworth-Springer, Ltd. Papers on geochemistry and cosmochemistry will be published in one of the principal languages, English, French, or German, with English summaries. Such papers are now widely scattered among a variety of journals and publications of scientific government bureaus.

Behre, Dolbear and Company announce the election of PARKE A. HODGES as Vice-President.

D. F. KIDD has been elected chairman of the B. C. section, Canadian Institute of Mining and Metallurgy for 1950. He has also been elected vice president of the Institute for District 6, which includes British Columbia and Yukon.

LEO H. SAARELA has been appointed commissioner of the Alaska Territorial Department of Mines to succeed B. D. STEWART, retired.

M. M. O'BRIEN, managing director of Bralorne Mines, Ltd., was reelected president of British Columbia & Yukon Chamber of Mines at the annual meeting in Vancouver in January.

D. D. IRWIN sailed February 16 from New York for a visit to Roan Antelope Copper Mines and Mufulira Copper Mines in Northern Rhodesia. He will join R. L. PRAIN, managing director of these mines, in Capetown, and with him will visit O'okiep and Tsumeb.

HENRY KRUMB has made available several scholarships, valued at $1,000 annually, to the School of Mines, Columbia University. These scholarships will be awarded to students interested in mining, metallurgical and mineral engineering.

The Third Petroleum Congress will be held at The Hague from May 28 to June 6, 1951. The sessions will consist of sectional meetings, plenary sessions and tourist and industrial excursions. Ten master sections are set up covering all phases of geology, geophysics, production, refining, utilization, construction, transport and economics.

JOHN K. GUSTAFSON, former Manager of the U. S. Atomic Energy Commission's Raw Materials Operations Office, has accepted an appointment to the Atomic Energy Commission Advisory Committee on Raw Materials.

RICHARD W. LOUNSBURY has been appointed instructor in geology, effective this fall, at Pomona College.

JOHN VAN N. DORR II, geologist with the U. S. Geological Survey, has gone to New Delhi, India, to conduct studies of mineral resources in the Province of Orissa. This work is being undertaken in accordance with a 1948 act providing for scientific and technical assistance and training grants to foreign countries under State Department auspices. During his stay in India, Mr. Dorr will advise the Indian Geological Survey as to what geophysical studies, diamond-drilling, or further geologic investigations may be required before actual drilling of known deposits is begun. The Government of India is mainly interested in the geological prospecting of metalliferous deposits such as chromite, copper, lead, zinc and graphite, and proving these and other deposits of bauxite, iron ores, limestones, and coal. Since the war Mr. Dorr has been in charge of the Survey's Mission in Brazil on a project mapping 4,000 square miles of an area rich in iron and manganese.

R. M. LEGGETTE has recently completed a tour as Distinguished Lecturer under the auspices of the American Association of Petroleum Geologists in which he lectured on the Elements of Ground Water Hydrology.

MORRIS M. LEIGHTON, the incoming President of the Society of Economic Geologists, started his functions on April 1st.